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1817

A PRACTICAL TREATISE

ON

MAKING AND REPAIRING

ROADS.

ILLUSTRATED BY ENGRAVINGS AND TABLES.

BY

EDMUND LEAHY,

CIVIL ENGINEER.

> " Our present modes of conveyance, excellent as they are, both require and admit of great improvements."
>
> QUARTERLY REVIEW.

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TO

GENERAL SIR JOHN FOX BURGOYNE, &c. &c. &c.

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PREFACE.

THE want of practical information on the subject of Common Roads has been much felt by those, and they are many, whose interests or wants are in great measure affected by the facilities of internal communication.

The importance of the subject needs not to be enforced or dwelt upon, and any information serving to simplify and elucidate the principles of this highly practical branch of knowledge must prove interesting in no small degree to the public at large.

The object of the following pages is to instruct those who may have to do with the making and repairing of roads and who, if they would serve their own interests or those of the public, must take care to provide themselves with useful information on their business, which, to be useful must be practical. Neither can a treatise on making and repairing Roads be devoid of interest for gentlemen of property and others who have a direct interest in good public roads, and are called upon to adjudicate upon the economical outlay of the public money.

Though the subject matter has been arranged with the view of adapting it as much as possible to the general reader, it was impossible to pursue some important branches of our enquiry without availing ourselves of the facilities which the *calculus* always affords in such investigations: whence it became necessary to depart in some degree from that simplicity so desirable in works of a popular nature. Still the matter of the following observations has on the main been kept quite clear of embarrassing calculations, which are confined to the last chapter; and even there we have endeavoured to present the general reader with the most important practical deductions arising from those investigations in a familiar form free from difficult calculation and the technicalities of science. Many of those deductions being new, and others differing widely from previously received opinions, we have deemed it equally due to the reader and to ourselves, fully to state the investigations upon which our conclusions are based.

It were not to be expected that the amount or quality of the information derivable from a small work, such as the following should satisfy professional readers for whom it is not properly designed though perchance it may not be unworthy of their notice. But if we succeed in bringing home, to the minds of those whose interests are concerned, the importance of careful attention to the details of road making and road repairing, and in developing the principles of this important though unostentatious department of practical knowledge, we reckon that we shall have done some service to the public, notwithstanding that we have chosen to tread in one of the most homely walks of Engineering science, the art of making and repairing of common roads.

In the comparisons instituted between the legislative provisions on the subject of Roads in respect to Great Britain and Ireland, and on the different systems practised in these and other countries, we have not ventured to offer any opinion at hazard, but have proceeded on the sure ground of what has fallen under our own observation in these countries.

In our professional engagements in England it happened to us to have more to do with Railways than Common Roads; but that circumstance has not prevented us from acquiring a thorough knowledge of the systems and details of the management of common roads in that country. In Ireland our professional and official engagements have brought us into close connection with the systems under which the common roads of that part of the kingdom are made and maintained; and with such opportunities we could not but observe the very great difference between the comparative cost of like works in both countries presenting in our mind matter worthy the serious attention of those who are charged with the care and management of the public interests.

The experiments made on the employment of machinery for stone breaking, and noticed in detail in the Sixth Chapter, prove that machinery may be applied to that purpose with more advantage because with greater economy than manual labor; and these experiments may, it is hoped, induce others to bestow upon the subject more attention than we have been able to devote to its consideration.

The Ninth Chapter on Draught, we venture to hope, may supply some information on questions interesting alike to the general reader and the professional Engineer. A subject so extensive in its nature and bearings, into the consideration of which there enter so many elements of calculation, the locomotive power, the roadway, its inclinations, and the vehicles employed for draught—such a subject might and could well afford ample matter for a separate treatise. If therefore we have not entered more at large into its consideration some excuse may be found in the limits within which a work such as the present must necessarily be circumscribed. At the same time, it is believed, the investigations of this Chapter elucidate to a large extent many of the subjects connected with draught, which heretofore had been either wholly overlooked or but imperfectly understood. The resistance to draught from irregularities of the road surface, and the sinking of wheels through a soft surface, both very serious impediments, are carefully investigated, and the results clearly establish the importance of preserving hard and smooth surfaces on common roads.

The effect of inclined roadways, which is to increase the mechanical draught in ascent and to diminish it in descent, is also investigated, and formulæ given by which to determine the material of which the surface should be formed on ascending planes so as to make the draught up such ascents no more difficult than upon an ordinary flat road. In the laying down of New Roads, it has long been a desideratum to ascertain by some certain principles the circuit on a flat road equivalent to travelling over an ascending and descending surface, or to determine when there will be less labor in going round a hill than in going over it. This subject has also been examined with no small care, and it is hoped that the Tables attached will facilitate any enquiry of the sort which may arise in practice.

In so far as we know, these investigations have the merit, whatever it be, of originality, for we are not aware that they have been ever given to the public in a form the same with or similar to that in which they are now respectfully presented. Should our enquiries have the effect of introducing, as we humbly presume to think they may, if attended to, more uniformity with greater accuracy in the design and construction of our roads, the object which we proposed to ourselves in presenting these pages to the public will have been fully attained; and we will count our humble labour abundantly repaid if we shall have contributed something, how little soever that may be, towards the advancement of one of the most useful branches of practical knowledge.

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HISTORY OF ROADS.

CHAPTER I.

THE benefits arising from good Roads are strikingly apparent in all civilized States. When a country is intersected by good roads, improvements of every sort will be carried forward with amazing rapidity. By diminishing the difficulties and expense of carriage, lines of road put the remote parts of the country more nearly upon a level with those in the neighbourhood of the town, and so they must contribute in a high degree to the advantage of town and country. They encourage the cultivation of the remote, which must always be the most extensive circle of the country. They are advantageous to the town, by breaking down the monopoly of the country in its neighbourhood. They are advantageous even to those parts of the country in the immediate vicinity of towns, because, whilst they introduce some rival commodities into the old market, they also open many new markets to the produce of those parts which before had the benefit of only one market.

Some of these benefits have been agreeably set forth in Dr. Anderson's *Rural Recreations*. Alluding to the advantages of good roads, he says, "Around every Market Place you may suppose a number of concentric circles drawn, within each of which certain articles become marketable which were not so before, and thus become the sources of wealth and prosperity to many individuals. Diminish the expense of carriage but one farthing, and you widen the circle; you form, as it were, a new creation, not only of stones and earth and trees and plants, but of men also; and what is more, of industry and happiness." The Abbe Renel remarks, "Let us travel over all the countries of the earth, and, wherever we shall find no facilities of trading from a City to a Town, and from a village to a hamlet, we may pronounce the people to be barbarous; and we shall only be deceived respecting the degree of barbarism."

It is little more than a century since some of the Counties in the neighbourhood of London petitioned Parliament against the extension of roads into the remote Counties.

Those distant places, they pretended, from the cheapness of labour would be able to sell all agricultural produce cheaper in the London markets than themselves, and would thereby reduce their rents and ruin their cultivation. Their rents, however, have risen and their cultivation improved, since that time.

The formation of good roads gives the greatest facility to commerce and contributes more powerfully, perhaps, than anything else to the progress of improvement. They have been denominated national veins and arteries, and the latter are not more indispensable to the existence of individuals than improved communications are to the healthy state of the public economy.

The Romans were particularly industrious in the construction of roads, which with them was considered of such essential importance that all the chief cities of their great empire were connected by roads, which for magnitude would vie with the greatest railway works and, as respects durability, must be admitted to surpass anything of the sort in modern times. At the present period, it would be considered idle to devote to such works the amount of labor which the Ancient Romans expended on their construction. Such was the permanence of their works, that even at this distant period the remains of them may be distinctly traced in almost every country occupied by that great people.

The principal cities were connected by immense roads, which have been alike the subject of astonishment and admiration. They ran in nearly direct lines without regard to natural difficulties, and the admirable contrivances by which these difficulties were overcome remain as magnificent memorials of Roman ingenuity and perseverance. In low and level grounds the roads were elevated to a considerable height above the adjoining lands and afforded an extensive view of the surrounding country: if the foundations were soft, piling was resorted to for the purpose of giving them sufficient solidity, and viaducts and immense retaining walls and arches and piers were constructed where it was necessary to gain elevations. The upper works, forming the crust of the roadway, were generally about three feet deep, composed of four strata in the following order, viz :—

1st.—The *Statumen* or foundation—all soft matter being carefully removed.

2nd.—The *Ruderatio* composed of broken tiles, earthenware, &c., set in cement.

3rd.—The *Nucleus*, being a bed of mortar.

4th.—The *Summa Crusta*, or outer coat, composed of bricks or stones.

Near Rome, the upper coat or pavement was of granite. In other situations hard lava was used, and jointed so closely that Palladio thought moulds must have been made for each stone.

The construction of roads was an object of state policy with the Romans, and the *Curator Viarum*, or Superintendent of the Ways, was an officer of great dignity amongst them.

Julius Cæsar was the first person of high rank among them who accepted the situation of Curator of the public ways, which was afterwards rarely conferred upon any but men of consular dignity. Thernus, a noble Roman, according to Cicero served this office, became Curator of the Flaminian Way, and was a colleague of Cæsar's. Pliny says in a letter to Pontius that the news of Cornutus Tertullus having accepted the surveyorship of the Æmilian Way affected him with great joy; and Statius also, in his Sylvæ, mentions among his eulogiums on Victorius Marcellus, who was of the prætorian order, that he had been selected by the Emperor Domitian to be surveyor of the *via latina*.

> "Quique tuos alio subtexit munere fasces;
> Et spatia antiquæ mandat renovare Latinæ."

He also mentions, as a mark of singular dignity, that Plotius Grippus, whom he calls *majoris gradus juvenem*, had been entrusted by the same Emperor with two of the most honorable offices of the empire; one of them being the care of the public ways, *præfectum annonæ et curatorem viarum*.—Lib. iv. Sylvarum.

The Appian Way was the most celebrated of the Roman roads, both on account of its length and the difficulties which it was necessary to overcome in its construction, and was hence called the "Queen of the Roman ways." It was made, as Livy informs us, by the Censor Appius Cæcus, about 311 years before Christ, and, in the first instance, was laid down only as far as Capua, a distance of about 125 miles; but even this portion of the work, according to the account of Diodorus Siculus, was executed in so expensive a manner, that it exhausted the public treasures. From Capua it was subsequently carried on to Beneventum, and finally to Brundusium, (a distance of about 350 miles,) when this port became the great place of resort for those who were desirous of crossing over into Greece and Asia Minor. This latter part of the Appian Way is supposed to have been constructed by the Consul Appius Claudius Pulcher, grandson of Cæcus, 62 years later, and to have been completed by another Consul of the same family 36 years afterwards. We find frequent mention made of repairs done on this road by the Roman Emperors, and more particularly by Trajan, both in the histories of the time and also in ancient inscriptions. This road seems to have been still in excellent order in the time of Procopius, who wrote in the sixth century and gives a very good account of the manner in which it was constructed. He says an expeditious traveller might very well perform the journey from Rome to Capua in five days.

Its breadth is such as to admit of two carriages passing each other. Above all others, this way is worthy of notice; for the stones which are employed on it are of an extremely hard nature, and were doubtless conveyed by Appius from some distant quarry, as the adjoining country furnished none of that kind. These, when they had been cut smooth and squared, he fitted together closely, without using iron or other substance, and they adhered so firmly to each other that they appear to have been thus formed by nature and not cemented by art. And though they have been travelled over by so many beasts of burden and carriages for ages, yet they do not seem to have been anywise moved from their place or broken or to have lost any part of their original smoothness. According to Eustace, the modern tourist, such parts of the Appian Way as have escaped destruction, as at *Fondi* and *Mola*, shew few traces of wear and decay after a duration of 2000 years. The same writer states the average breadth of the Appian Way at from 18 to 22 feet.

The *Aurelian* road, which connected Rome with Gaul, has occupied attention in modern times. Amidst the devastations that attended Bounaparte's march through the countries on both sides of the Alps, some of his measures ultimately tended to facilitate the intercourse between Italy and the rest of Europe. By the improvement of this ancient Roman road in 1801—5, the passage across that mountain range by the Simplon has been changed from an almost impassable mountain track to a safe and splendid carriage way inclining about two degrees, or nearly one in thirty from a level. Almost unparalleled difficulties were encountered in the construction of this great work. Galleries and Tunnels of great magnitude were carried along the sides of frightful precipices and driven through immense mountains, which, as engineering works, will remain as lasting memorials of Napoleon's greatness and ingenuity.

It has been already observed, that the most considerable of the Roman Roads were paved with accurately jointed stones; but gravel roads made with small stones were by no means unusual, and their permanency was secured by a judicious and careful distribution of excellent drains.

The comfort and ease of travellers appear to have been well provided for along the Roman Roads in Italy. Porticos were distributed along the sides at convenient intervals to afford shelter; and temples, ædicula, triumphal arches, villas, groves, gardens, &c., were thrown together in the most picturesque manner.

The great military Roads of the Romans were from Thirty-six to Forty feet wide, of which the sixteen feet middle were paved—at each side there was a raised path two feet wide, which again separated two sideways each eight feet wide. The breadth of the Roman roads, as prescribed by the laws of the twelve tables, was but eight feet; and the width of the wheel tracks which are traceable even at this day are not above three feet.* The extreme parts of the empire were connected with the Capital by Twenty-nine great military roads, equal to nearly 48,500 English miles.

The Carthaginians, according to Isidore, were the first who paved their public ways; but roads appear to have been constructed at a very remote period by the Persians.

The Greeks do not appear to have paid much attention to roads. Herodotus simply says, that among the Lacedæmonians the management of their ways was wholly invested in their kings. Strabo says, that the Greeks neglected three objects to which the Romans paid especial attention—the cloacæ or common sewers, the aqueducts, and the public ways. The Greeks made the upper part of their roads with pavements of large square blocks of stone, whilst the Romans mostly used irregular polygons. The ancient road from Iolis to Carthæa, according to

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* The Roman foot measures, 967 of ours, or about 11, 3-5th inches.

Tournefort the finest thing of the kind which can perhaps be found in all Greece, still exists. He traced it for three miles, flanking the sides of the hills and standing by a strong wall, the coping of which consisted of immense blocks of a greyish stone.

The roads of France, like the ancient Roman Ways, appear to have been laid down more with the object of making short and direct lines of communication than lines of easy or favourable draught. They are generally from thirty to sixty feet wide, the middle sixteen feet being paved; but once a vehicle leaves the pavement it becomes a matter of much difficulty to extricate it from the soft and muddy surface of the sides. For this inconvenient plan and defective mode of repair, the better plan of the broken stone surface is now generally substituted in France as well as in these countries—indeed the practice of repairing roads with small broken stones appears to have been used in France under the direction of M. Turgoz in the last century before its general adoption in these countries. Under the altered practice, or rather the return to the mode which formerly obtained the great post roads of France, the roads which make the communications between the principal towns of the kingdom, are rapidly improving, and in some provinces will not be found inferior to some of the best kept roads in these countries But the cross roads, which form by much the greater part of the roads of the country, are very much neglected, and are in many places quite impassable for heavy carriages. In some places they are so bad that riding is unsafe with any but the horses or mules accustomed to their rugged and rutty surfaces. Much of the evil complained of is to be attributed to the state of the road laws of France, which, by placing the repair of roads under the immediate and exclusive direction of the executive power, relieve the residents of the provinces from that care and supervision which they could so well and so advantageously exercise.

A Minister, high in office, may take pleasure in executing a work of splendour and magnificence, such as a great highway, but to execute a great number of comparatively small works, which excite but little or no admiration, in the traveller, and in short have nothing to recommend them but their utility, is a business, which however important to the interests of society, appears unworthy the attention of one placed in an office of high authority. Under such regulations therefore these works are almost always neglected.

The roads of Germany and Prussia resemble those of France, but in Holland and the low countries, Belgium, &c., the surface is almost exclusively composed of thin bricks like tiles, which under light work make a very pleasant carriage-way. Sweden is well supplied with excellent roads, for which it has long been famous ; and in Russia the very few roads made are said to be well executed.

Mr. Coxe mentions, that "The high roads of

Sweden wind agreeably through the country, are made with stone or gravel, and are as good as our turnpikes in England; and yet not a single toll is exacted from the traveller. Each landlord is obliged to keep in repair a certain part of the road, in proportion to his property; and for the purpose of ascertaining their respective portions, small pieces of wood or stone marked with numbers and capital letters, are placed at different distances on each side of the way. Such indeed are their goodness throughout the whole country, that several thousand miles may be travelled over, without meeting fifty deserving the appellation of indifferent. They are also as pleasant as they are good, and in many places look like gravel walks carried through gentlemen's grounds and plantations, as they wind through the fields and extensive forests, the lofty trees casting a gloomy shade with their overhanging foliage."

In America, the common roads are almost entirely superseded by Railroads, with which that immense country is now intersected in almost every direction.

It is difficult to ascertain the precise period when the roads of the United Kingdom first became available for wheel carriages. It does not appear that they were used for such purposes in England previous to the Roman invasion; and there is no likelihood of their having been so employed in Scotland or Wales before that period.

In Ireland, it is not unlikely that they may have existed at a yet earlier date. If we examine the Round Towers for which it is singularly remarkably, we find, in many instances the stone of which they are built to have been procured from distant places; and there is nothing unreasonable in the supposition, that good roads and wheel carriages assisted in procuring materials for these ancient buildings, the period of whose history was enveloped in remote obscurity even in the days of Giraldus Cambrensis in the Twelfth century. We may observe that a people who have executed such works, must have had a system of roads adapted to their purposes, no less perfect than those of later times. We are not to judge from the scantiness of historical records that might serve to throw light on the subject; for our knowledge of even comparatively late periods, is but very imperfect, owing to a variety of vicissitudes. In England or Wales there are no buildings of equal antiquity with the Round Towers of Ireland; there are therefore no such data to assist in determining the antiquity of roads in those parts of the kingdom. No doubt there existed some few traces of roads in Britain before its invasion by the Romans, but then the surface was composed exclusively of earth, scarcely deserving the character of a road, and obviously was not used for wheel carriages. The Romans, in laying down their military roads adopted some of the old trackways. Of these the principal were the *Foss Way* reaching from Totness in Devonshire through Cirencester and Lincoln to North Britain, and *Ikenild Street* extending from Southampton through York to Newcastle upon-Tyne. At the present time scarce any traces of these works can be found. Near Chester some remains of compact pavements are occasionally found, with several feet of soil upon them, and from the fact of that town having been a great Roman *depôt* there is scarce any doubt of these remains being a portion of one of their roads. Similar traces have been found between Musselburgh and Abercorn in Scotland.

For many centuries after the invasion of Britain by the Romans, articles of trade were transported from one place to another upon the backs of horses, commonly called *Pack-Horses*. Even so late as the middle of the last century, almost the whole of the land carriage of Great Britain and Ireland, was on the backs of horses, and we find, at the present day in most of the mountainous districts, the principal traffic carried on by the same mode of carriage. By degrees however when civilization advanced and commerce became more extended, the creation of agricultural wealth in the interior districts of the country would enforce the adoption of some mode of communication suitable to an advanced state of improvement; and the use of wheel carriages and hard and smooth roads where the weight that could be conveyed by a horse would be considerably greater than what he could either drag upon a sledge or carry on his back would proportionally extend the facility of internal traffic.

It were needless to dwell upon the many benefits which good roads, with the general use of wheel carriages must confer upon any country.

Before the establishment of roads suited to such vehicles, the ordinary burdens of the country were conveyed in panniers on horses backs; manure was brought in the same way to each farm: and the produce of the land was conveyed in like manner to the markets and seaports. The effect of such a state of things must of necessity have restricted the operations of the cultivator to a very small sphere as the cost of transit, when so expensive and slow, would not allow him to bring new lands under cultivation nor to carry the produce of the old to a profitable market. Now however by the aid of good roads, the panniers have been superseded by wheel-carriages the effective performance of the horse is increased twenty-fold, the sphere of occupation is enlarged, and districts are brought under profitable cultivation which before lay waste and profitless. The farmer may now feel satisfied of being able to convey the produce of his land to market, and may place twenty times a heavier load upon his horse without doing him any injury.

In whatever country a well arranged system of communication has been established, it has invariably been found to be productive of the greatest advantages commercial and agricultural: almost every branch of industry may be traced to this as to its source; and it were needless to add that some of the most obvious natural advantages would be wholly valueless without good roads as a means of intercommunication.

SYSTEMS OF

MAKING AND REPAIRING ROADS.

CHAPTER II.

THE systems under which the construction and repairs of public roads are conducted differ very much in the kingdoms of Europe and even in Great Britain and Ireland. In England the principal roads are maintained by turn-pike trusts out of tolls levied upon travellers, and the repairs are executed under the controul of the Boards of Trustees and their Officers. Besides these Boards of Trustees, every Parish is obliged to maintain the cross roads out of funds and labour commonly known as *statute labour,* to which also the turn-pike trusts lay claim when their other funds are insufficient. This labour each occupier of land is obliged to contribute and for its enforcement provision is made by various acts of parliament. Much of the recent excitement in certain districts of Wales is attributable to the enforcement of this law, and without attempting to palliate the outrages of the Welsh population, it may be pronounced, a thing in some degree unreasonable that the occupiers of the land should be compelled to contribute to the repairs of roads by labour and taxes and afterwards obliged to pay toll for using these same roads upon the most ordinary occasions.

From the returns made to Parliament in 1839—40 it appears that in England there are 21,962 miles of road repaired under Turn-pike Trusts, the tolls from which amounted to £1,776,586 annually; whilst the expenditure exceeding the gross receipts by £3,763 amounts to £1,780,349. The length of each Trust-road averages $16\frac{3}{4}$ miles, upon each of which a regular staff of officers is maintained, such as Clerks, Treasurers, Surveyors &c. The salary paid to each Surveyor is about two guineas per mile per annum, and owing to the combination of many trusts under one Surveyor, each of their salaries usually amounts to £800 per annum. The Clerks frequently get £300 per annum, but the office of Treasurer is usually filled by some member of the Trust without salary.

The extent of Parish Roads appears to be 104,772 miles, costing annually for highway rates exclusively £1,168,207 16s.; and the number of Surveyors and Deputy-Surveyors or Way-Wardens is 20,000 being upon an average one Way-Warden or Supervisor for 5¼ miles of road, besides a proportionate number of other officers such as Secretaries Clerks, Accountants, &c.

Of the sum expended by Turn-pike Trustees £129,124 was paid for management; and permanent improvements cost £197,658, leaving a sum of £1,453,567 for the expense of repairs alone, or something over £66 per mile per annum. In addition to this immense levy, the Trusts have incurred debts to the enormous amount of £8,577,132 8s. 7d. The evils of the English system of road management under Trustees, now grown so formidable, have long been felt; and although the subject has occupied the attention of several committees of both Houses of Parliament, the evil still remains unabated and their labours have in effect done nothing towards its removal beyond a recommendation to consolidate the numerous Trusts and place them under the management of a Central Board.

It may not be uninteresting to give a brief sketch of the new plan for maintaining the Welsh and English Turn-pike Roads, submitted to the Lords' Committee, and printed in their Report to Parliament in the year 1833.

Proposed new arrangement of the English and Welsh Turnpike Roads.

"No vacancy of Trustees to be filled up after the passing of this Act.

All Trustees of Roads at present legally admitted shall be

Trustees on all Roads within the County or Counties in which they are at present acting, together with the High Sheriff of the County, the Chief Magistrate of every Borough within the County, the acting Justices of the Peace of the County, and all and every person having in his own right, or in the right of his Wife in Fee or in Life-rent, Freehold or Copyhold, Land within the County of the Annual Value of £300, exclusive of the value of Houses or Buildings of any kind and above Reprisals.

No Alteration, Deviation or Improvement of any part of the Roads in England and Wales, exceeding the ordinary repairs shall be made, unless referred to, and approved by the General Board hereinafter to be named.

A Board to be appointed by His Majesty for the purpose of Inspecting the Accounts of Trustees of Turn-pike Roads, for appointing General and Deputy General Surveyors, and for examining, and controlling the affairs of Roads under certain regulations and restrictions, consisting of

The Post Master General, President,.......	———		
Six unpaid Commissioners,................	*Unpaid.*		
Three paid Commissioners at £1000 a year each	£3000	0	0
One Comptroller, he being a practical man..	1,000	0	0
One Professional Adviser,................	300	0	0
One Secretary,..........................	500	0	0
One Clerk,..............................	200	0	0
Incidental Expenses.....................	1,500	0	0
Carried Forward,............	£6,500	0	0

Brought Forward, ... £6,500 0 0

The Kingdom to be divided into Two Parts under the direction of Officers, whose salaries are to cover all their personal and travelling expenses as follows:

First Part to consist of One General Surveyorship, containing Three Districts, comprising Eight Deputy General Surveyorships, viz.

Berks, ... 16 Trusts 280 Miles.
Hants, ... 34 ...... 675 —
Wilts, ... 31 ...... 549 —

Deputy Gen. Surveyorship, 1,504 Miles—*Salary* 1,000 0 0

Somerset,.... 22 Trusts 850 Miles.
Dorset,...... 16 ...... 389 —

Deputy Gen. Surveyorship, 1,239 Miles—*Salary* 800 0 0

Devon,...... 27 Trusts 866 Miles.
Cornwall,.... 13 ...... 348 —

Deputy Gen. Surveyorship, 1,214 Miles—*Salary* 800 0 0

The above Seven Counties, embracing 159 Trusts, and containing 3,957 Miles, to form the *First District.*

Carried Forward, ... £9,100 0 0

Brought Forward,			£9,100	0	0
Norfolk,	14 Trusts	288 Miles.			
Suffolk,	14	299 —			
Cambridge,	12	204 —			
Essex,	12	266 —			
Deputy Gen. Surveyorship, 1,057 Miles—*Salary*			800	0	0
Kent,	47 Trusts	668 Miles.			
Surrey,	21	296 —			
Sussex,	49	636 —			
Deputy Gen. Surveyorship, 1,600 Miles—*Salary*			800	0	0
Hertford,	9 Trusts	150 Miles.			
Bedford,	12	189 —			
Huntingdon,	4	61 —			
Northampton.	23	365 —			
Oxford,	22	287 —			
Bucks,	12	179 —			
Deputy Gen. Surveyorship, 1,231 Miles—*Salary*			800	0	0

The above Thirteen Counties embracing 253 Trusts, and containing 3,888 Miles, to form the *Second District.*

Gloucester,	45 Trusts	836 Miles.			
Worcester,	32	472 —			
Warwick,	33	450 —			
Deputy Gen. Surveyorship, 1,758 Miles—*Salary*			1,000	0	0
Carried Forward,			£12,500	0	0

Brought Forward, ... £12,500 0 0

Rutland, ...	3 Trusts	48 Miles.
Leicester, ...	22	294 —
Stafford, ...	56	820 —
Salop, ...	47	646 —

Deputy Gen. Surveyorship, 1,806 Miles—*Salary* 1,000 0 0

The above Seven Counties embracing 238 Trusts, and containing 3,564 Miles, to form the *Third District.*

One General Surveyor for the First Part, with a Seat at the Board when in Town, ... 2,500 0 0

Second part to consist of One General Surveyorship, containing 3 Districts, comprising 4 Deputy General Surveyorships.

Notts, ...	20 Trusts	265 Miles.
Derby, ...	40	609 —
Chester, ...	33	449 —
Lancaster	53	547 —

Deputy Gen. Surveyorship, 1,870 Miles—*Salary* 1,000 0 0

The above Four Counties containing 146 Trusts and 1,870 Miles to be the *Fourth District.*

Yorkshire,	103 Trusts	1,481 Miles.
Lincoln, ..	26	455 —

Deputy Gen. Surveyorship, 1,936 Miles—*Salary* 1,000 0 0

Carried Forward,............ £18,000 0 0

Brought Forward, ...	£18,000	0	0

Durham, ...	16 Trusts	441 Miles.
Westmorland,	11	272 —
Cumberland,	13	275 —
North-umberland,	15	416 —

Deputy Gen. Surveyorship, 1,404 Miles—*Salary*	800	0	0

The above Six Counties to be the *Fifth District.*

Wales, ...	86 Trusts	2,001 Miles.
Monmouth,	10	269 —
Hereford,..	15	418 —

Deputy Gen. Surveyorship, 2,688 Miles—*Salary*	1,600	0	0

The above Two Counties of England and the Twelve in Wales to be the *Sixth District.*

One General Surveyor for the Second Part, with a Seat at the Board when in Town,........	2,500	0	0
	£22,300	0	0

Four pence in the Pound on the Road Income of England and Wales will produce	25,000	0	0

PERSONS.

Board,	11
General Surveyors,	2
Deputy General Surveyors,	12
	25
Future Resident Surveyors,	500
Clerks	250
Treasurers,	40
	815
Present Persons employed,	3,627
Number of Persons decreased,	2,812

Cost of Board's Establishment	22,300	0	0
250 Clerks, say at £200 each,	50,000	0	0
Printing, Stationary, Charges, &c., on 1000 Trusts, average per annum £25 each,	25,000	0	0
	£97,000	0	0
Present Charge for England and Wales,	196,000	0	0
Making a Saving per annum of	99,000	0	0

As soon as the whole Kingdom can be arranged, and Surveyors placed regularly in the proportion of about One to every Forty Miles of Road, 500 persons (each keeping a horse) at £100 per annum each (equal to £50,000 a year) will be required; but that is not deducted from the Saving of £99,000, because on every Trust that has been properly regulated, even for a short time, the Surveyors have been paid out of the Funds, whatever the amount might be, allowed for ordinary repair and wear; therefore no additional expense under proper control and regulations. Their wages are the best spent money on a Trust, and will, under such circumstances, prove the surest source of economy.

The Board in London to have power to require the Trustees to dismiss any Officer of their Trust of whose conduct or abilities the Board may have reason to disapprove.

The Board to Report annually to Parliament."

The imperfect systems heretofore obtaining in the management of common roads has at different periods engaged the attention of the Government with the view of devising some improvement in that branch of our national policy. It is now a question for serious consideration whether our road system should not receive every possible improvement as by doing so there can be little doubt we should give a powerful impulse to the developement of the almost untouched agricultural wealth of the kingdom.

The system of following the ancient line of road, Mr. Edgworth observes, has been so pertinaceously adhered to, that roads have been sunk many feet, and in some parts many yards below the surface of the adjacent ground; so that the stag, the hounds and horsemen have been known to leap over a loaded waggon in a hollow way without any obstruction from the vehicle.

It is worth observing, that when land was comparatively of small value, it was more difficult to obtain ground for a new road than it is at present when a square yard of land costs more than would have purchased a perch of land in former days. The fact is, general knowledge has been so diffused of late that the prejudices of farmers and landholders have yielded to calculation; they perceive that good roads are profitable as well as agreeable, and that whatever facilitates communication increases the demand and secures a ready price for all commodities. Why many roads still continue without alteration or repair, is a question that cannot be easily answered. In hilly countries one reason may be assigned for this neglect: a certain number of horses are absolutely necessary to raise a given load up the hills, and the same number of horses are sufficient to drag it through the worst roads in the intervening level ground. Any spot of marshy or rugged road that requires a strong team to drag the carriage over it, will have the same effect as a steep hill, in making it indifferent to the waggoner what the rest of the road might be, as he must have a certain number of horses to get over some particular obstruction in his way. It is not pretended that these are the only causes which prevent the amendment of our worst roads; the system of parish repairs of highways in England, is in itself sufficient to prevent improvement.

In all countries, similar systems have been found unpopular. One of the heaviest complaints of farmers in France at the revolution, arose from the oppression of the *Corveés*, and the recent disturbance in Wales may be traced to a somewhat like cause, yet nothing appears more equitable than that a district should keep its own roads in repair.

In fact nothing but a general system for all the roads of the kingdom can be effectual; it is in vain that one parish repair its roads, if its neighbours will not do the same; for the neglect of any one part renders the whole impassable without a team of sufficient strength to get over what has been neglected.

The cross roads in France and Ireland are better than those in England; because in France they are now under the immediate superintendence of the government and in Ireland under the care of Grand Juries at Assizes. It has been said that the establishment of turnpikes caused the first general attempts to the improvement of roads; though this may be the fact, yet it is equally true that many of the turnpike trusts in England have failed, and that many of them are not only deeply in debt, but insolvent. These failures have arisen from various causes; but one obvious defect is common to most of these *trusts*: they have borrowed money from individuals to make the roads in the first instance, and the interest of the capitals have been paid out of the tolls, leaving scarcely any thing for keeping the roads in repair. Now to secure a fund for repairs the money expended on the road should in no ways interfere with the produce of the tolls, which should be exclusively appropriated to improvements and repairs.

In Ireland the public roads are divided into four classes, each maintained under a distinct body. The first class and that far the most extensive comprises the County roads maintained exclusively by a land tax under Grand Jury Presentments.

The second class embraces the roads maintained by the Board of Works which are comparatively but few.

The third class includes those roads maintained by a toll levied by Turnpike Trustees, being also but few.

The fourth class consists of the streets and approach roads to certain Cities and Towns, repaired by local Street-Boards whose charge is much less extensive and burthensome than the supervision of any other portion of Roads in Ireland.

The County roads, maintained by Grand Jury Presentments at the expense of the Baronies through which they pass, cover a length of 38,407 Miles and constitute far the most extensive part of the roads of Ireland. In the County of Cork alone, which is about a tenth part of the kingdom, there are 3,365 Miles maintained under the Grand Jury law and the expense of the last year ending at 1843 has been £29,147 9s. 3d., being eight pounds thirteen shillings and three pence per mile per annum; and it is believed that under any other existing system whether Turn-pike or other, the average cost of maintenance will be found to exceed the expenditure upon the County roads in a large proportion. Indeed with reference to the County of Cork it can be stated with certainty that the average cost of the Turn-pike roads is three times greater than the cost of the County roads, whilst the state of repair of the latter is generally much better than that of the former.

There is very ample room for improvement in both. But the Turn-pike roads, it may be safely said, are maintained during the winter months in a condition barely sufficient to render them passable; and at all seasons they will be found to want that solidity so essential for the public convenience and for the ordinary purposes of communication. They are most part left to the management of unprofessional men, and have no well regulated system of supervision.

The Roads maintained by the Board of Works are well executed, but the average cost will be found to exceed that under the Grand Jury system for the same description of road. The expense of the roads maintained under the former may be taken at about £11 per mile per annum, and they are usually in remote districts where no very considerable intercourse exists. The general system of the Board of Works is to appoint a superintendent to about 200 miles, and under him there are from ten to twenty overseers, who direct the repairs by daily labour, having been previously supplied with broken stones by contract.

If the entire repairs were contracted for under the direction of the Superintendent, it is believed that they would be executed more economically, and that the average cost would not exceed that of the County roads. Of this we have had a practical proof in the instance of the Skibbereen and Crookhaven road about 20 miles long which is superintended by us without any charge to the Board. We advertised the repairs of it for them in two contracts and for a period of three years, and they have been executed fully as well as other roads of the description and for £6 per mile per annum, clearly proving the greater economy of the contract system.

The cost of roads maintained by the Local

Boards in Cities has risen to an excess quite disproportioned to all others or to the intercourse existing upon them. This extravagant expenditure may in some degree be accounted for by want of system and the neglect of the most ordinary rules for road repairs. Nothing can exceed the filth of these towns, nor can any thing be more wasteful than the system under which repairs are conducted. As an instance, it may be mentioned that under the Local Board for the City of Cork there are 46 miles of Streets and Roads embracing an area of about 27,862 square perches, for repairing which, including cleansing and watering, the annual levy is upwards of £6,000, making an average of £130 per mile per annum, which is fully cent per cent over the sum for which the repairs could be effected under proper system.

Notwithstanding this enormous expenditure, the Streets of the town and the approaches through the suburbs are kept in the most unsatisfactory condition. In one section of the town, the surface is little better than a succession of ruts and holes—in another the health and convenience of thousands would seem to be utterly unheeded: filth is allowed to accumulate in the narrow and populous lanes; and the atmosphere is contaminated in localities which require cleanliness more than the wide streets and well circumstanced houses of the more wealthy inhabitants. The approaches and suburbs are if possible worse—in the rainy season an extremely irregular surface is always covered with a thick coat of fluid limestone mud, which the tramping of horses will splash around in every direction, and when the weather happens to be dry, the road with its immediate neighbourhood is enveloped in clouds of dust to the great annoyance of passengers and of the citizens who crowd these delightful suburbs.

A strong evidence of the imperfect systems of Local Town Boards is furnished by the operation of the Act, 6 & 7, Vic. c. 32, in the City of Cork. That Act extended the jurisdiction of the Local Street Board beyond the old suburbs to the new municipal boundary, taking in 2,200 lineal perches of road previously maintained by contract under the general Grand Jury Laws for an *annual* sum of *one hundred and thirty-five pounds*. Now however that this extent of Road has been transfered to the care of the Wide Street Board the contract-system is abandoned and so large a sum as *Nineteen Hundred Pounds* a year is levied off the City for the maintenance of what had previously cost only £135 a year.

If we compare the effects of the existing arrangement of County Presentments with any other system for the execution of public works, we must come to the conclusion that under the former the greatest amount of work has been obtained for the smallest sum of money.

The same result may be expected from any other arrangement based upon the Contract System provided it be effectually worked through all its details. This will be best secured under such an arrangement as will secure a sufficient amount of individual responsibility, and no arrangement can do so without being so far stringent in its nature as to compel the full performance of every contract.

Particular care should be devoted to the preparation of agreements and specifications, setting forth for each Contract only such works as the exigency of the case should require. This cannot be expected under any Board or System without a large share of the professional assistance of an engineer; otherwise a wasteful expenditure of the public funds will be the obvious result, not only in the outlay upon unnecessary works but also in the imperfect execution of really useful works. Such results at all times mischievous, would it is easy to see entail upon society a large amount of injury at no distant period, and would exhaust much of the resources that under proper management would have served to advance the substantial interests of the community.

The following is a list of the Counties of

Ireland, shewing the length of road maintained by Grand Jury presentment, and the number of Principal and Assistant Surveyors in each—taken from the Report of the Grand Jury Commission in 1841.

COUNTY.	Miles of Road Repaired.	Number of Principal Surveyors.	Number of Assistant Surveyors.
Antrim,	1,900	1	12
Armagh,	917	1	6
Carlow,	540	1	1
Cavan,	1,200	1	3
Clare,	1,170	1	3
Cork—East,	1,904	1	5
Cork—West,	971	1	3
Donegal,	2,482	1	5
Down,	2,560	1	7
Fermanagh,	868	1	2
Galwey—East,	957	1	none.
Galwey—West,	900	1	none.
Kerry,	950	1	2
Kildare,	806	1	3
Kilkenny,	816	1	5
Kings County,	729	1	2
Leitrim,	652	1	1
Limerick—East,	556	1	1
Limerick—West,	576	1	1
Londonderry,	1,450	1	4

COUNTY.	Miles of Road Repaired.	Number of Principal Surveyors.	Number of Assistant Surveyors.
Longford,	534	1	none.
Louth,	400	1	3
Mayo,	1,400	1	4
Meath,	1.700	1	1
Monaghan,	1,142	1	4
Queens County,	689	1	2
Rosscommon,	959	1	none.
Sligo,	584	1	2
Tipperary—North,	972	1	3
Tipperary—South,	2,089	1	4
Tyrone,*	1,200	1	none.
Waterford,	600	1	4
West Meath,	820	1	none.
Wexford,	1,544	1	4
Wicklow,	870	1	3

The Irish Grand Jury Road Act regulates the mode by which County roads shall be maintained.

That Act, 6th & 7th Wm. 4, c. 116, an extract from which is appended, authorizes the Grand Jury of each County to enter into Contracts for the maintenance of the Roads within it for a period not exceeding seven years. Contracts are usually for no more than three years in Cork County, where there are at present upwards of one thousand seven hundred, each averaging about two miles in length.

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*There is no Return for Tyrone in the Commissioners Report.

It is only at each Assizes that Grand Juries can put roads under contract, and even then their powers are limited to the granting or refusing such as may be sent to them from a previous meeting of Magistrates and *selected Cess-payers* held in each Barony. There is one such meeting held previous to each Assizes, to consider and decide upon applications for contracts upon roads and all other public works for which the Baronies are liable to taxation, such as New Roads, building and repairing Bridges, repairing Roads &c. The County Surveyor attends each meeting and prepares Plans and Specifications with forms of Tenders for every work approved thereat; and thereupon, but at an adjourned meeting, the Baronial Bench contract with parties for the execution of each work. The Bench are compelled by the provisions of the Grand Jury Act before mentioned to accept in each case of the lowest tender, provided the party so tendering finds two sufficient securities for double the amount of his offer.

The several works *approved and adopted* by the Baronial meetings, and the contracts for executing them, are submitted to the Grand Jury at the succeeding Assizes, and they are empowered to grant or refuse them as they shall think proper; but they have no power to alter or modify them in any degree, from the manner in which the Baronial meetings may have determined upon.

Thus the Grand Jury controls the acts of each Baronial meeting,* whilst neither body is empowered to engage in any work however small without the sanction of the other.

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* The Grand Juries are furnished at each Assizes with a list of one hundred names from each barony being the highest Cess-payers therein; and they select any number not exceeding Twenty-four, who are thereupon *qualified* to be associated with the Magistrates at the Baronial Sessions.

Great public inconvenience often arises from this arrangement, there being no power left in any quarter to warrant the repairs of any road however useful, which by accident or otherwise may not have been put under contract at the Assizes; and it is by no means unusual to find very important lines of communication so circumstanced without any adequate means of guarding against the inconvenience.*

One-half that number are drawn by lot, and with the Magistrates decide upon all applications brought before the meeting; but the same Cess-payers cannot be selected to be associated with the Magistrates at two successive meetings. Both Magistrates and associated Cess-payers and all County Officers are disqualified from engaging or being interested in any County contract.

* Sudden Breaches in Roads or Bridges, caused by Floods or such accidental circumstances may be repaired by the order of two Magistrates made at Petty Sessions, or of the Grand Jury at the Assizes.

Two Magistrates cannot authorize a greater expenditure than Ten Pounds for Roads or Twenty Pounds for Bridges

There are generally about eight months between the Summer and Spring Assizes, and any line, save Mail-Carriage Roads, not previously contracted for must remain neglected during that long period, which embraces the season of the year that acts most injuriously upon roads—the winter months. Such cases might be provided for by allowing a special application after the usual public notice, to be submitted and entertained on the first day of each general quarter sessions of the peace, and if approved, by entering into a contract for the immediate repairs and proper maintenance of the damaged road or bridge or whatever it might be until the succeeding assizes, when it could be placed

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so damaged, but the power of Grand Juries is unlimited in this respect—and neither the one nor the other can authorize the repairs of any sudden breach unless it shall have occurred so recently as not to admit of an application to Road Sessions in the ordinary way.

The Post Master General can direct the Repairs of any neglected road upon which the Mails are conveyed in *Wheel Carriages.*

under contract in the usual way. Thus not only would the inconvenience arising from neglect or accident occurring from assizes to assizes be effectually prevented but also in all likelihood a large expenditure at a future time would be saved to the public. When the occurrence of such accidents is not only probable but certain, the omission of any provision to meet the contingency is a palpable defect in the existing state of things. Other and serious objections are found to exist against many provisions of the present Road Act as well as against its omissions. The provision requiring a preference to be given in all cases to the lowest bidder has been productive of considerable difficulty in securing the proper maintenance of inportant lines of communication. It is to be recollected that if the public gain a something by giving works to the lowest bidders, they are at the same time sure to lose by rejecting a good Contractor whose superior attention and skill are often more than equivalent to the pecuniary gain derived to the public by the employment at a lower nominal cost of less skilful hands.

No doubt some difficulty might occasionally arise in guarding the exercise of a discretionary power from abuse, but under every state of things, objections of one description or another will be found to exist; and therefore the best system under all circumstances will be that which best consults for the public interest with the smallest amount of inconvenience. That the system of low contracts is not the best of all systems follows from the preceding remarks and must appear evident upon a very little reflection. No doubt the stipulated salaries of negligent Contractors can be withheld and their contracts quashed, but the very necessity of applying such remedy presupposes the existence of a bad road; with all the inconvenience thereby occasioned to the public; and upon the commonly admitted principle that prevention is better than cure, it were obviously better to do away altogether with the necessity of such a course by at once adopting a better system, under which as the evil in question could not arise so neither would the remedy be called for.

Once a man becomes a bad contractor, he should not again be allowed to undertake the maintenance of any road in the district, much less be received upon equal terms with one who proves himself efficient in the performance of the duty he undertakes. The absurdity of the present law which makes no distinction between the good and the bad contractor must be very obvious indeed.

Under every circumstance and in all cases the system of Contracting by public competition should be strictly followed; still it cannot be denied that the exercise of a sound discretion in selecting Contractors, would be found to operate with the most salutary effect; and the exercise of such discretion could hardly fail to be sound when open to the eyes of the public and liable to be canvassed with a just severity.

The regulations under which payments are made to Contractors are extremely inconvenient and seriously demand revision—when a contract is effected for the repairs and maintenance of a road, a registry is made of the Contractor's name, stating the length of road under his care, and the rate per perch per annum for which he has contracted according to the specification of the County Surveyor. In all cases where the contract is properly fulfilled the Grand Jury at the following assizes make an *order* for payment of the stipulated salary; but that *order* is the only authority for levying the amount under the existing law, and therefore the Contractor is obliged to wait for payment until the following assizes when the levy is paid into the County Bank. Thus the Contractor is twelve months before he receives any payment, and there can be no doubt that the effect of such delay is very injurious to the Contractor and to the public also. Payments could be made half-yearly by levying the amount of each Contractor's salary concurrently with the granting of the contract; and the Contractors whose neglect would disentitle them to their salaries at each assizes, could be debarred from a future application and their salaries re-presented to the credit of the Baronial charges in aid of future levies.

It must be admitted generally that the system of County Contracts is by no means free from defects; but yet it must be obvious to those conversant with its operation, that it has worked very well and that by the introduction of judicious amendments it is susceptible of much improvement. With its admitted defects, no other existing system is so strongly recommended by experience and none certainly can compare with it upon the score of economy, since it cannot be questioned that it has given the largest amount of work with the smallest expenditure.

The present law under which County roads are repaired has had a trial of ten years, whence it is no wonder that the working of its details should be partially clogged by unforeseen defects or trifling omissions which experience would point out and time rectify. But as yet most certainly no sufficient case has been made out for transferring to other Boards that control over the execution of County works which Local Session Meetings and Grand Juries can exercise so efficiently and so economically. If improper persons are sometimes selected to act at Session and Assize Meetings and if sufficient means have not yet been devised for controlling their proceedings and insuring the execution of none but really useful works and with the greatest economy of the public funds, some apology may be found in the recency of the system, which can be ameliorated in time by amending the Act that defines and regulates its operations. Whatever be the existing defects it must be admitted that the interests which the present law was designed to guard and to advance have been in the main materially served. The valleys and mountain ranges never before traversed by the path of industry have been intersected by excellent roads; large tracts that lay waste beyond the memory of man have been brought under cultivation; improvement has found its way into almost inaccessible districts which have exchanged the wildness of unreclaimed nature for the smiles of fertility; and where the marsh exhaled its' vapor and the hill was covered with its' barren heath the eye is now gladdened with the sight of pastures and corn-fields. The scanty population which formerly struggled for a precarious subsistence, debarred in effect from intercourse with others, have given way to an energetic and industrious population; and sounds of living industry now greet the ear of the traveller where formerly he might have been indebted to the accidental civility of the mountaineer for discovering his way through the intricacies of the scarce beaten path.

These are evidences of improvement and growing national wealth which present themselves to our observation in connexion with the existing system of County Contracts; and a system to which we can trace such effects as to their cause must be admitted to have worked well for the public good notwithstanding the partial defects incidental to its' operation.

The defects and abuses of the Grand Jury laws in existence immediately before the present system of County Presentment, were too palpable not to be felt and loudly condemned; and the disposition to find fault with the present system may take its rise from confounding the one system with the other and attributing to the present one the imperfections which in truth apply only to its predecessor, while the beneficial results of the system now in operation are either wholly forgotten or but little attended to.

Taking the County of Cork which is about one-tenth of Ireland in extent and population, we find under the present Grand Jury law, now ten years in operation, new roads and works executed of unusual magnitude, the extent of roads maintained by presentment nearly doubled, an immense annual increase of expense for the Constabulary Crown prosecutions and other public burdens not existing under the previous law; *nevertheless the taxation of the County of Cork for the last ten years since the introduction of the present law, does not exceed the taxation of the preceding ten years by quite* ONE PER CENT.

It is much to be regretted that the Commission lately appointed to enquire into the working of the Irish Grand Jury law should not have made themselves acquainted with those facts before they agreed to a report setting forth the present law as one not to be recommended on the score of economy. With all respect for the opinion delivered in that Report, it cannot be reconciled with the actual experience of the last ten years in so large a portion of the kingdom as the County of Cork.

The following tabular return of the levies upon the County of Cork under the old and the present law for the last twenty years, has been prepared with the greatest care from the County records and may be relied upon as strictly correct.*

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* I am indebted to Mr. W. Murphy for this table which has been extracted from a most instructive and useful summary of the County taxation prepared by him with much labor and ability.

LEVIES UPON THE COUNTY OF CORK.

UNDER THE OLD GRAND JURY LAW. 59th Geo. 3. c. 84.		UNDER THE PRESENT GRAND JURY LAW. 3rd & 4th Wm. 4, c. 78, and 6 & 7 Wm. 4, c. 116.	
YEAR.	AMOUNT.	YEAR.	AMOUNT.
1824	£72,803 12 11	1834	£76,988 1 1
1825	82,116 7 7	1835	62,798 18 6
1826	83,585 19 6	1836	70,666 18 5
1827	89,715 5 6	1837	68,265 14 4
1828	69,832 6 10	1838	78,951 7 1
1829	72,969 2 7	1839	77,809 7 5
1830	63,112 19 2	1840	84,866 12 0
1831	67,834 12 6	1841	80,719 15 11
1832	69,375 5 8	1842	79,995 11 4
1833	80,621 1 3	1843	77,379 5 11
Ten Years.	751,966 13 6	Ten Years.	758,441 12 0

Total for Ten Years ending at 1833 ...... £751,966 13 6
Total for Ten Years ending at 1843 ...... 758,441 12 0

Difference 6,474 18 6

Making a difference of less than *One per Cent.* upon a comparison of the levies for equal periods of Twenty Years.

Ireland presents a very remarkable contrast with England in respect to the comparative economy of their road system. In England it appears that the maintenance of 21,962 miles of Turn-pike roads cost annually £1,453,567, whilst according to the cost of the County of Cork roads the same length would be maintained in Ireland for £190,337. From the great increase of agricultural wealth in Ireland and the consequently increased transit of produce on its roads, it is believed that the average amount of *road* intercourse cannot be very much greater in England.* Besides the load of a horse upon the English roads rarely exceeds fifteen cwt. whilst in Ireland it may be fairly stated at 20 cwt. Indeed 25 cwt. is a usual load and even 30 cwt. is not uncommon. These two circumstances taken together, the greater heaviness of the loads in Ireland while the average intercourse in each country is nearly the same, afford a fair enough test for estimating the comparative excellence and durability of the roads in both countries.

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* The large number of canals which intersect almost every County of England, relieve the roads from much of the heaviest intercourse.

If we compare the expense of constructing new roads in England and in Ireland, we shall arrive at the same result as in respect to repairs.

In the County of Cork 627 miles of new roads have been made by County Presentment within the last twenty years for a gross sum of £165,212 14s. 6d. giving an average cost *per mile* of £263 9s. 6d.

In England the cost *per mile,* according to Mr. Hughes's estimate given in the latter part of his work on roads, is £4,457.

The difference of cost per mile in England and Ireland is very remarkable and out of all proportion with the difficulties of construction and the quantity of labor required in both countries.

Upwards of 300 miles of new road in the County of Cork have been designed and executed under our direction, the planes of inclination or gradients upon which are generally about one foot perpendicular rise for every forty feet in length; and the excavations and embankments are in the main as heavy as on the English common roads.

The comparative estimate we have given of the expense of road-making in both countries is not the statement of a theorist without experience, but of one who has the means of speaking from practical knowledge and may therefore be relied upon as one of unquestionable accuracy.

It is true a variety of causes may contribute to raise the average cost of making and maintaining the English roads; yet after due allowance for all, there still exist between the systems of making and keeping the roads in England and Ireland, and between their respective expenditures a difference of sufficient magnitude to challenge the attention of those to whose supervision such interests are entrusted.

MODE OF

MAKING AND REPAIRING ROADS.

CHAPTER III.

The best mode of surface repair is that which secures the greatest degree of hardness, smoothness, and firmness at the smallest expense.

Various modes of making and repairing roads have from time to time been practised, and after a full and oftentimes an expensive trial they have been succeeded by others which in their turn have given way to some more novel method. Experience has now established the superiority of broken stone from eight to ten inches thick for the upper crust of ordinary roads, not only because of the economy of this method but also on account of its general adaptation to all localities, and its decided superiority in point of comfort and ease to paved surfaces. The other modes of repairing and forming a road surface include, Rubble-stone pavements, Ashlar or cut stone pavements, wood pavements, and wheel tracks of cut stone and iron. Each has been tried in turn and found to possess peculiar advantages suited to particular situations more especially to towns and places of great intercourse.

Each too has had its advocate contending zealously for its superiority and general adoption. Without attaching ourselves to any particular system for all varieties of circumstances, there can be no doubt that considerable advantages would attend a combination of those methods by applying each to the peculiar situation and circumstance to which it is best suited. For instance where unavoidable acclivities occur, a wheel track of iron or cut stone, laid on the left side, being the proper place of an ascending carriage, would reduce the friction at the surface and make the draught up hill so easy that in many cases it would be diminished below that on an ordinary *flat* road.

The noise of vehicles rolling over pavements is almost intolerable in towns of considerable intercourse whilst a broken stone surface is comparatively noiseless; for which reason added to its' superior safety, the latter surface is confessedly better adapted to the ordinary intercourse in Cities and Towns. The expense of keeping the Streets of a Town clean and in good order will be cheaper with broken stone than with a paved surface in the ratio of about two to five on a moderate comparison, and the broken stone will be found much less irksome than the rugged and noisy pavement.

No doubt pavements are more durable than broken stone as a road crust, and of this we have very strong evidence in the instance of the ancient Roman roads. The surface of the Roman roads was composed almost exclusively of cut stone pavement; many of them still exist in good preservation, though made over two thousand years. It is within the last fifty years that pavements were generally superseded by broken stones which latter may now be said to be the general mode of making and repairing roads.

A broken stone road possesses great facilities for maintenance beyond what pavements present. Partial repairs regularly applied on a broken stone surface will secure a good carriage way, whilst it will be necessary to take up a large portion of good and permanent surface of a pavement in order to remedy a comparatively small defect. This arises from the lateral pressure which always exists in a pavement whilst undisturbed, and although this pressure operates effectively in preserving a paved surface, yet when even a partial disturbance takes place its state becomes altogether different and the lateral pressure which previously operated as a preserving then becomes a destroying principle. The action of a pavement resembles that of an arch; when a portion is removed, the lateral pressure of what remains having lost its resisting medium, loosens the surface crust for a considerable distance around, and renders extensive relaying necessary where comparatively partial repairs and outlay would have answered with a broken stone surface. In considering the relative advantages of paved and broken-stone surfaces, it is important to bear in mind that the former may be repaired without any particular interruption to ordinary traffic, whilst repairs cannot be carried on upon a paved surface without a total suspension of intercourse in the mean while.

This presents an inconvenience extremely embarassing and injurious to the public; so much so that it is often deemed better to endure the annoyance of a very bad pavement even until it becomes almost untravellable rather than submit to the greater inconvenience of repairing, which would put a full stop to intercourse for some time.

On steeps and even upon partial inclinations pavements become very dangerous from the want of footing for horses. It is said that at Blackfriar's Bridge a greater number of horses in proportion to the number passing over have been thrown for want of footing or hold upon its paved surface than at any other place in the kingdom. The same inconvenience was had to be encountered by vehicles ascending Ludgate Hill, and it was found necessary to lay the pavement in a peculiar way in order to diminish the inconvenience. The new pavement was laid so as to present an indented surface similar to a fluting or grooving represented in Fig. 1.

The squared stones being laid across the street upon an indented or inclined bed, one edge projected above the adjoining one and upon a longitudinal section resembled the teeth of a saw. This method proved quite successful in preventing accidents, but the noise of the many wheels passing along this great thoroughfare was increased to an intolerable degree and even at the risque of safety the blocks so laid had to be reset level as before.

Rubble stone pavements are made with large gravel lumps somewhat resembling a large egg, and usually about ten inches long by four inches thick set on end upon a bed of coarse sand about three inches thick, into which they are driven by a heavy wooden *maul* weighing about seventy pounds worked by two men. The stones should be *mauled* down firmly to a uniform surface slightly convex in the middle and coated over with a layer of fine gravel one inch thick. In the formation of paved as well as broken stone surfaces it will be found necessary to drain the subsoil perfectly. The cost of such pavements will mainly depend upon the convenience of stone and the price of labor. In Cities the price will be found between six pence and ten pence per square yard, whilst in other localities where paving stones are cheap and wages low, it will not exceed four pence the yard. A good pavior will set *three and one half* square yards in an hour, requiring two labourers to prepare and level the ground and bring stones, besides two men for ramming and mauling down who will be able to serve the work of six paviors.

The cost of *workmanship* per square yard can therefore be easily calculated. Putting the wages of a pavior at four shillings and labourers at eighteen pence per day, the cost of *workmanship* per square yard will be as under:

	Cost per Yard.	
One pavior executing 36 square yards at 4*s.* 0*d.* per day will give	0	1⅓
Two and one-third labourers to attend and maul down each pavior's work at 1*s.* 6*d.* per day for 36 square yards will give ..	0	1$\frac{1}{6}$
Cost for workmanship per square yard..	0	2½

The cost of paving stones must vary according to their local convenience but they may generally be procured for about three to four pence per square yard; and sand can be had for about one penny the square yard.

Cut stone or ashlar pavements are formed with hewn blocks of the form of parallelopipeds being generally eight to twelve inches deep and about eight inches wide by eighteen inches long.

Their use is chiefly confined to streets of considerable intercourse, the foundations being prepared alike to rubble pavements, the blocks are laid in regular courses across the carriage way and are bedded firmly and closely as in the arch of a bridge. Should the blocks be wider than eight inches, a champhered groove runs across the upper surface of about one inch in depth; and in all cases the edges are chamfered or cut so that when the blocks of each adjoining course are set the joint will shew a like groove, the object of which is to afford sure footing for horses. Such pavements will be found very durable, not requiring frequent repairs like rubble pavements, for which reason they should always be preferred wherever there is a great thoroughfare. In other respects this description of road surface is liable to the same objections as rubble pavements, causing the like disagreeable noise and when out of order requiring extensive relaying.

The extra expense of cut stone compared with rubble pavements will be confined principally to the labour in dressing the blocks and generally may be averaged at from four shillings to six and six pence per square yard. If there be Footways on the sides, the blocks next them should be firmly abutted against the curb stones. This description of pavement possessing as it does the principle of an arch is very permanent, but yet from its quickly wearing into a smooth surface becomes extremely dangerous to horses and therefore deficient in one of the most essential conditions of a good roadway, namely *safety*.

Paving with blocks of *wood* has lately been tried in New York in North America, in St. Petersburgh, and in London. The experiment appears to have been very successful in the last named city, where over 100,000 yards have been laid down, possessing beyond any doubt the advantage of cleanliness and freedom from disagreeable noise whilst at the same time the surface is firm, safe and durable in a high degree. The first method adopted in laying those pavements was by cutting the timber into hexagonal blocks measuring about nine inches on every dimension and setting them on a firm broken stone or concrete foundation. But that mode of forming the wood blocks soon presented an obvious defect. The small surface embraced under each block being seperately acted upon by each vehicle passing over it, the concrete or stone foundation at once received that pressure from the manner in which the blocks were laid and soon became indented, so that the irregularities of the substratum were at once exhibited by the surface of the wood pavement and the contour of the latter assumed all the appearance of a roadway disfigured with ruts..

Various ingenious methods have been adopted to meet this evil, the blocks now laid are generally cut into the forms of parallelopipeds each about eighteen inches long by twelve inches wide and from three to eight inches deep, grooved and tongued together so as to embrace a large bearing surface and thereby prevent the injurious action upon the foundation to which the first mode was liable. With this arrangement each side of a block can be turned up to the surface according as any one becomes abraded.

The first cost of the blocks for a wood pavement will not be found so expensive as upon first view might be supposed. The wood Paving Company established in London under the protective provisions of a patent will deliver their paving blocks at any seaport in the kingdom at from 7s. 9d. to 7s. 0d. per square yard. This Company is entitled to a Royalty of one shilling per square yard upon every yard laid down by any other company or person. The following list shows their charge per square yard for blocks of different depths:

	s.	d.
Six Inches thick at	7	9
Five Inches do.	7	6
Four Inches do.	7	3
Three Inches do.	7	0

and so on diminishing three pence per inch in thickness. But if the foundation be well prepared and covered with a layer of broken stone or concrete six inches deep, the wood blocks of *five inches thick* will be found sufficient for roads where the most extensive traffic is carried on and where there must consequently be the greatest wear of the highway. A good concrete may be made by mixing a half bushel of hydrolique lime, a quarter bushel of clean sharp sand and five bushels of clean river gravel or broken stone, which quantities being mixed to a good consistency with water and spread evenly will be found to afford the necessary thickness for one square yard.

The cost of setting the wood blocks will be about three pence per square yard.

Experiments have been made with the view of determining the relative superiority of wood and stone pavements, and the result of these experiments is that wood pavements are more durable,* present greater facilities for traction, make less noise, have less of mud or dust and require less expense for their maintenance.

From the experiments by which its superiority has been tested and proved, wood paving is likely to obtain general adoption; its chief defect is its slipperiness in wet weather, but in every other respect it appears to be a material superior to any hitherto employed for making the upper crust of streets in populous cities. To prevent inconvenience from slipperiness the surface of the blocks is grooved across the direc-

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* In a paper read before the Scottish Society of Arts, by Mr. Hope, on the wear and tear of granite compared with wood during a period of 18 months, he gives the following results.

	Wood.	Granite.
At the end of 1st Month	.017	.014
— 2nd —	.030	.025
— 3rd —	.040	.037
— 6th —	.062	.073
— 9th —	.071	.112
— 12th —	.096	.141
— 15th —	.111	.183
— 18th —	.125	.208
	.552	.793

tion of draught. The sides of the grooves are usually sloped to an angle at bottom being one inch in depth, one inch wide, and about four inches apart, which is found to afford safe footing for horses. A practice was adopted in St. Petersburgh of laying over the wood with a thin coating of *pitch* sprinkled with *grit* to prevent slipperiness; and in London some of the earliest wood pavements were cemented with pitch and the sand thrown over the surface. But these methods tended much to the creation of mud and experience proves that wood pavement cannot be kept too clean or free from any extraneous mixture. Wood alone grooved in the manner described affords a sure footing and permanently clean surface, and the *dry* timber blocks laid closely together without pitch or other cement than the key of wood already described, will swell from the absorption of moisture which they quickly imbibe and become so tight and firm as to supersede altogether the necessity of cement. Even in the driest weather they will retain sufficient moisture to insure a necessary degree of coherency. If the blocks are laid with the fibres in a vertical position they will be found to suffer least abrasion or injury.

Roads of considerable extent are now in progress of construction through the interior of Canada in North America, the upper crust of which is formed with planks from three to four inches thick laid in one length across the roadway, the surface and sides of each plank are sawed square and laid closely together, bringing their upper surfaces to a uniform level. There is yet no sufficient experience of this mode of construction to warrant any very decided opinion as to its probable efficacy; but from the unfavorable position of the fibres when subjected to the action of vehicles and horses feet, they will be likely to suffer abrasion very rapidly. To this we may add that where the elements of surface, so to speak, are so large and unwieldy a partial repair must be a work of much greater difficulty than would attend the repair of a road made with small blocks such as we have described.

The essential parts of M. le Large's memoir on pavements given in the third volume of "*Les Machines Approuvées*" of the French Academy is thus quoted by Mr. Edgeworth.

Stones in common pavement are usually somewhat oval from five to seven inches long, and from four to six inches broad. They are laid in parallel rows on the road or alternately as bricks are laid in a wall.

On the pavement Fig. 2 wheels slip from the round tops of the stones into the joints between and soon wear away the edges of the stones and their own iron *tire*. By degrees channels are thus formed between some of the stones, and in time the pavement is ruined.

On the pavement Fig. 3 where the stones are placed alternately to prevent the injury to which the former method is liable, the wheel sliding sideways makes a channel between two stones, and is then obliged to mount from the groove which it has made, to the top of the stone opposite to it; when it has attained this situation, the wheel may slide sideways, or may go forward over the top of the stone before it, till it drops into the interstice between the two next stones. By continual wearing, these ruts become so wide and deep that the wheel does not touch the stones on either side, nor does it reach the ground between them, but it bounds from one to the other, thus jolting the carriage in every direction. This method is not at present in use.

In the pavements hitherto described, the stones are but of a small size, but if flat stones of twelve or fourteen inches long are well laid, wheels are not liable to slide into the joints; and if such stones are laid with their longest sides crossing the road, they are less liable to injury; but still narrow wheels sometimes fall into the joints between the largest stones, and having in time worn away their own edges, and those of the stones, they will act like wedges and will displace the stones. No pavement of the best stone that could be procured can long resist this action of a narrow wheel. And the only effectual means of preserving pavement is to increase the breadth of all wheels to at least three inches.

Were no wheels narrower, a cheap and durable pavement might be made of flat stones not more than three inches square, provided they were eight or nine inches deep to give them reciprocally lateral support; for the tier of such broad wheels could never sink between the joints of the stones. But in all pavement, the first thing to be attended to is the foundation. This must be made of strong and uniform materials well rammed together, and accurately formed to correspond with the figure of the superincumbent pavement. This has no where been more effectually accomplished than in some pavements in Dublin. Major Taylor who was at the head of the paving board, before he began to pave a street first made it a good gravel road and left it to be beaten down by carriages for several months, it then became a fit foundation for a good pavement. When the foundation has been thus prepared care must be taken that each stone is at least eight inches deep, that it should bear broadly and firmly on its base; and that the whole should be rammed repeatedly to make the joints close, the upper and lower sides of the stones should be as near each other as possible, but they should not touch laterally, except near the top and bottom leaving a hollow in the middle of their depth to receive gravel which will serve to keep them together. This method of paving may be easily executed by common workmen who may throw in gravel between the stones as they are laid down. It may be easily conceived that if a grain of gravel inserts itself into the holes that are in stones opposite to each other they will *dowel* them together. It will be useful to cover a newly made pavement with gravel, which will preserve the fresh pavement for some time from the irregular pressure of wheels till the whole is consolidated. It should be observed that the stones should be of equal hardness, or soft stones will be worn down into hollows.

M. le Large, in his Memoir, has exaggerated the obstruction occasioned by the wheels of a carriage bounding from one stone to another. Whenever a wheel falls and rises alternately the *vis insita* of the carriage preserves much of the force acquired by the fall, to assist it in rising again. M. le Large calculates the loss of power to a carriage rising half an inch at every paving stone, to be equal to what would draw it up a hill rising a hundred and twenty six feet in a mile. This calculation is certainly beyond the truth.

It is scarcely necessary to add that in every species of paving no stones should be left higher or lower than the rest; for a wheel descending from a higher stone will by repeated blows sink or break the lower stone upon which it falls.

Perhaps iron pavement might be practicable.

The hardest stones soon give way at the edges, but coarse refuse iron might be tried without any great expense. It should be cast with a rough surface upon which horses feet might have a proper hold; this inequality of surface would impede the motion of wheels but very little. Whether such iron pavement should consist of large or very small pieces is a question that cannot be determined without experiment. The expense would in the first instance be very considerable, but its durability might perhaps be found to compensate for a large original disbursement.

M. le Large has in his Memoir, recommended very strongly narrow tracks of a superior kind of pavement in the nature of stone railways. He supposes that no inconvenience would arise from the meeting of carriages on such a trackway; because he takes it for granted that all carriages would return empty from the Capital. A supposition of a very extraordinary nature! Such stone railways have been recommended to a Committee of the House of Commons by Mr. Matthew's in the first Report of May 1808, and were some years since as travellers may have seen in actual use at Milan and other Continental towns.

Though railways on a common construction are not applicable to the traffic that goes on near a large city; it is yet well worth considering whether they might not be advantageously adapted to great roads. On such roads when they are sufficiently broad railways might be placed on each side of the road. On these small waggons for heavy burdens linked together might be drawn, and carriages for swift conveyance might be received in cradles suited to railways: and thus light carriages may be transported on railways without any alteration in their present construction, so that coaches and chaises may travel for any convenient distance upon any public railway, and may turn off instantly to a common road.

Steam engines may also be employed to draw all kinds of carriages, which in turn may drag all sorts of machines with any requisite velocity without interruption.

With respect to broken stone roads a considerable diversity of opinion exists among practical men as to the best mode of preparing the *sole* of the road before receiving the broken metalling with which the surface is to be formed. Some contend that draining the subsoil is the only preparation necessary before applying the broken materials or metalling, and that this might be done with advantage even upon the worst soils, whilst others insist upon a foundation pavement under the broken stone as essential for a good roadway.

The advocates of Mc Adams and of Telford's systems of road making urge these opposing views and each party presents practical proofs apparently strong and as in their opinion unanswerable, to establish the necessity of adopting under every variety of circumstances the system for which they respectively contend. To such lengths are their views pushed that even in the case of roadways over rock bottoms, some of those who take up Mr. Telford's views will contend that a pavement is desirable between the broken stone surface and the rock. Again, those who coincide with Mr. M'Adam will insist with full confidence, that once the subsoil is drained no other preparation is necessary, and that the broken stone metalling being laid upon even a boggy or sandy bottom will insure a firm and permanent roadway, without any further preparation than making the depth of the broken stone crust from eight to ten inches.

Without engaging the reader in a controversy upon the relative merits of these two plans, or the sufficiency of either in peculiar situations, thus much may be laid down as certain that each possesses advantages suited to particular circumstances, and that both would be found inefficient upon a boggy bottom. In the latter case a stratum from 12 to 18 inches thick of stiff clay as a soling under the broken stone, the bog surface beneath being previously well drained, would be found the most effectual means of insuring a proper and sufficient foundation for the carriage way. Whether stones be arranged as a pavement or otherwise, unless such a coating is placed between them and the bog they will continually sink through the turf, and the roadway will require constant metalling without much apparent advantage. A coat of stiff tenacious clay forming a compact flooring over the bog and embracing a wide surface prevents the metalling from penetrating weak spots under the pressure of heavy loads. Where there is a fine sandy bottom and stiff clay cannot be conveniently procured, rough pavements or concrete from six to twelve inches thick under the broken stone will be found the best mode of securing a firm roadway over them; but in *ordinary* cases "*pitching*" or pavement under the broken stone, which is always expensive, is quite unnecessary. Experience has proved generally, that broken stone alone laid upon a well drained subsoil, is sufficient to render the surface durable and uniform at all seasons, not to speak of the great advantages of economy and simplicity.

When a road is to be repaired the first thing to be done is to ascertain the depth and description of metalling upon it. No new stone will be necessary when the depth exceeds eight inches in the centre and four on the sides, but the surface should be loosened and all stones exceeding two inches in the greatest dimensions being raked to the sides should be broken sufficiently small to pass through a ring of 1¼ inches diameter. When the crust is loosened all surface wavings and irregularities should be dug off and removed so as to bring the entire to an uniform figure having the middle elevated above the sides; whereby there is obtained a cross fall for the discharge of surface water, which however should not be greater than one inch to each yard. The large stones raked out of the road and broken at the sides should then be spread in *thin layers* upon the parts where the metalling is deficient in depth. The most approved figure for the cross section of a road surface is a segment of a circle. Against this shape it is urged as an objection that the middle or crown is too flat and the sides too steep, but when it is considered that the entire rise of the crown above the sides ought not to exceed five inches on a road thirty feet wide, and a rise less in proportion for a less width, the difference of ratio in the cross fall of a circular segment will not appear very material. Theoretically considered the objection to the segment of a circle is well founded, but experiment has clearly shown that the objection exists only in theory. The depressed sides will answer as Water-tables to receive the surface waters which should be discharged at regular intervals through pipes or openings under the Fences. The Water-tables should be kept quite clear from mud or other matter so as not to obstruct the free flow of the water, and should be carefully formed with the view of tapping and discharging any lodgements of water on the road side. Water suffered to rest on the sides penetrates the surface and saturates the roadway to a considerable distance around; the ill effects of which soon manifests itself in the general wreck of the road crust and the simultaneous working up of the earthy subsoil, whence the surface is converted into a loose heterogeneous mass of mud and stone.

It is of great importance to form the edges of Water-tables (which are in fact the sides of the road) as straight as possible or to give them a uniform curvature according as the line of the road happens to be direct or bending. The practice of making Water-tables like Trenches is not to be recommended it being quite unnecessary to give them any remarkable degree of depression below the sides of the road. The dip from the middle of the Roadway towards the water-tables should be a uniform inclination as far as the edge of the water table, where the inclination may be somewhat steeper than that of the cross-fall from the centre of the road.

When it becomes necessary to convey the surface water from one side of the road to the other, a covered drain should be made across from one water-table to the other and below the metalling of the carriage-way. The water-tables have been oftentimes connected by a paved channel running right across the surface of the carriage way; but these transverse surface drains are to be condemned since whatever may be their use in other respects they serve as most effectual spring-breakers whenever a carriage is urged over them with a speed much exceeding the rate of a walking pace.

The broken stone or gravel used in repairing or making roads should be free from any mixture of sand, earth or other substance, and of a size to pass freely through a ring of *one and one-half inches diameter*.

For repairs, in particular, it will not be found advantageous to use larger materials and as far as practicable all should be of equal size. Road materials should be hard* and laid on very closely in compact sheets, not in drills or small patches; and in making repairs care should be taken not to scatter about the materials in a loose slovenly manner. The surface of the roadway should be perfectly cleaned from mud or dust before the metalling is applied, and in no case should gravel or stones be used of smaller size than would pass through a *half inch ring*.

When the maintenance of roads is let by contract for a given time, it will be found of no small public advantage to include among the express conditions of the contract the keeping in proper order all protecting Fences, Walls, and other such works which may be considered in a manner as appurtenances of a public road.

This additional care will increase but little the expenses of the Contractor or of the public that pays him, but it will save a large waste of the public money because it will render unnecessary the frequent reconstruction of works which a little care and a little expense regularly applied in time will preserve from ruin.

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* To obtain a smooth surface, it is essentially necessary that road materials should have an uniform degree of hardness.

A newly made road requires very particular care for some time to prevent the loose materials from forming into ruts—a binding of clean gravel would be found advantageous, and greatly diminish the irksomeness usually felt in driving over fresh loose metalling.

The general state of repair of our Roads is very variable indeed; some are kept very indifferently and others in very fair order; but their condition generally speaking, does not approach to any thing like uniformity, which nevertheless were a thing greatly to be desired. The inconvenience of great diversity in the state of roads must strike any one of common observation. If a horse at the outset of a journey have a load placed upon him fully equal to his strength upon a good road, it will be too much for him on the bad parts he has to pass over; and so on account of the different state of our different lines of road part of the horse's effective strength must be lost or else the animal must be over-weighted, which is equally bad. It is therefore highly desirable, that the public roads should approach as near as possible to uniformity, especially as regards the degree of their hardness and other circumstances facilitating traction and that can in general affect, so to speak, their travellable condition. The breadth and finish in other respects might vary according to the proximity of towns or the nature of the particular traffic carried on; but as ordinary roads intersecting the interior of the country are mostly used for agricultural purposes requiring heavily loaded carts, they should be made as *hard* as other roads and as capable of *sustaining* the pressure of considerable *weights*.

When new roads are to be made they should be laid out between their *termini* as direct as the features of the country will permit; but Mr. Edgeworth truly remarks, to follow with this view the mathematical axiom, that a straight line is the shortest that can be drawn between two points, will not succeed in making the most commodious roads; hills must be avoided, towns must be resorted to, and the sudden bends of rivers must be shunned. All these circumstances must be attended to, therefore a perfectly straight road cannot often be found of any great length. It may perhaps appear surprising that there is but little difference in length between a road that has a gentle bend, and one that is in a perfectly straight line. A common road ten miles long and perfectly straight can scarcely be found anywhere; but if such a road could be found, and if it were curved so as to prevent the eye from seeing farther than a quarter of a mile of it in any one place, the whole road would not be lengthened more than one hundred and fifty yards. It is not proposed to make serpentine roads merely for the entertainment of travellers, but it is intended to point out that a strict adherence to a straight line is of much less consequence than is usually supposed, and that it will be perfectly advantageous to deviate from the direct line to avoid inequalities of ground. It is here that the skill of the engineer is to be exerted, a skill that is seldom apparent in the laying out of English roads.*

It is obvious that where the *arc* described by a road going over a hill, is greater than that which is described by going round it, the circuit is preferable; but it is not known to every overseer that within certain limits it will be less laborious to go round the hill though the circuit should be much greater than that which would be made in crossing the hill.†

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* This observation equally applies to the unnecessary and almost reckless expenditure of money on the English railroads under circumstances where slight and easy deviations from a straight line would in great measure save the necessity for immense tunnels, deep excavations or heavy embankments. The American engineers by their practical adoption of this view chiefly, have succeeded in constructing Railroads for little more than a tenth of the expense of the English lines.

† It is an important proposition in practical Engineering to ascertain when there will be less labour in going round

Where a hill has an ascent of no more than one foot in thirty, the thirtieth part of the whole weight of the carriage, of the load, and of the horses must be lifted up whilst they advance thirty feet. In doing this, one thirtieth part of the whole load continually resists the horses draught; and in drawing a waggon of six tons weight, a resistance equal to the usual force of two horses must be exerted.—*Edgeworth's Roads.*

The following brief directions for making and repairing roads will be found to embrace most of what is essential for the proper execution of such works. And although these directions are not intended to instruct the operator under all varieties of circumstances, yet we believe they contain useful general directions applicable to the ordinary cases arising in making and repairing roads.

In making roads through difficult countries,

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a hill than in going over it; or to determine the *lengths of horizontal lines, equivalent to ascending and descending planes.* The investigation of this important proposition will be found in the subsequent chapter on Draught.

unusual and extensive works often become necessary, requiring distinct and specific provisions for their execution. It is not supposed that the following directions are sufficient for any such cases, on the contrary they are as already stated intended only for those of ordinary occurrence.

General directions for Laying-out, Forming, Fencing, Draining, and Metalling a New Road.

LAYING OUT THE ROAD.

1. The road should be laid out and made in strict conformity with the Maps, Plans, and Sections of the Engineer.

2. The *Road* throughout its whole length need not be of uniform width: Twenty-five feet in the clear of fences and side drains, will be sufficient in ordinary cases; but in deep cuttings or high embankments, the breadth might be reduced to 18 or 20 feet.*

3. The *line*, at every bend or turning should have an easy curve, a segment of a circle, and

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* Approaches to cities should be from 40 to 50 feet wide.

where curves of contrary flexure or different radii meet, they should be tangents to each other at such point.

4. The *levels* of the road as marked upon the Sections should be strictly adhered to, that is to say, the Road should be brought, by cuttings and fillings, to the inclinations shewn on the Sections.

FORMING THE ROAD.

1. The *sole of the Road* should be formed with an even smooth surface.

2. The *two sides* should be brought to the same level and the centre elevated above them so as to have a cross fall each way of one inch in a yard.

4. In *embankments* or made ground, if the filling be of bog-stuff, it shall have an addition of one-fourth of its intended height; and if of clay or earth, of one-twelfth, so that after consolidation, it may not sink below the intended level.

5. In all embankments or excavations of Bog-Soil, the side slopes should not have less than

two feet base to one foot in height. Embankments should be built in regular courses with berms or off-sets each one foot wide on the field side of the fences. In every instance of an excavation through Bog, side drains should be cut, parallel to the Road and to a permanent depth of four feet under the level of its surface.

6. When *cuttings or fillings* are of soft clay or earth, they should have side slopes of one to one-and-a-half; and when of stiff clay or earth, one to one—that is, one foot in perpendicular height to one-and-a-half base in the former case; and one foot in perpendicular height to one foot base in the latter.

7. But *if cutting* should occur in very stiff hard clay or earth, the side slopes may vary between one to one and three to one.

8. When the *line of Road* passes over soft bog soil, not exceeding one foot in depth, the bog stuff shall be dug off, and sound filling substituted therefor. But if the bog be of greater depth, the surface is to be rendered equal to the

support of the road materials, by sinking deep and wide drains on each side with proper outlets, to allow the water to run away freely to a level of four feet under the road and covering over the bog sloughs with the firmest turf, dried peat heath or brush-wood laid evenly and regularly so as to break joint. The boggy surface is then to be covered with a soleing of clay or earthy gravel, to the depth of at least 10 inches, and this allowed some time to settle and consolidate, when unbroken stones six inches in depth should be laid as a rough pavement before the application of gravel or broken stone.

9. When the *Road* passes over springy ground or spouty clays, cross drains are to be cut from the springs and sloughs into the grips one foot square and filled with small stones; if necessary, holes or pits should be sunk and filled with broken stones, so as to form a tap for the water.

10. When the *Road* is to be made on the side of steep sloping hills on which an embank-

ment, having any of the *side slopes before mentioned,* would not rest, it will be necessary to cut the entire width of the Road out of the hill or to cut a part of the width out of the hill, and support the embanked portion by a retaining and guard wall.

11. The *base of the embankments* should be protected from floods by proper stone fences where necessary.

12. Depôts for broken stones should be formed within 200 yards of each other along the line of the Road; the Depôts to be semi-elliptical having the transverse diameter 24 feet long in the line of the fence; the semi-congugate to be 8 feet. They are in every instance to have a fall towards the road of 1 to 8.

DRAINS GRIPS AND FENCES.

1. Drains for conveying running water, should have side walls of dry masonry 14 inches thick, paved on bottom if necessary; the openings not to be less than 18 inches square well secured at the ends by large stones. The covering flags

should be at least one foot under the sole of the road and from four to five inches thick.

2. Where a road is cut on the side of a hill, drains should be sunk 30 inches deep on the sides, below the intended surface of the carriage-way and filled with broken stones—these drains should be 6 inches wide at bottom and about 12 inches wide at top: proper cross drains should be formed from them to the nearest low ground or outfall.

3. *Fences* should be made on both sides of the Road for its entire length except where excavations exceeding 3½ feet deep occur; they should be built with earth, faced with sods or stone, 5 to 6 feet thick at bottom, 3½ feet high and the top set with a double row of English furze seed. Pipes or openings should be made through the Fences at every 50 yards to permit the water to escape from the surface of the road into the side drains or grips.

4. *Grips* should be made on both sides of the road, at the field side of the *Fences*, for

its entire length except where broken stone or covered drains are made in excavations under the water-tables, or where the roadway is embanked two feet high or more above the adjoining land; they should be three feet deep below the roadway formed to run dry and not hold stagnant water; and should be 18 inches wide at bottom, the sides sloped as in other excavations.

5. In *made ground,* where the outside is two feet or more under the Road, no side drain will be required; but a fence of 3½ feet high will still be necessary over the level of the Road.

6. In *steep sloping ground* there should be a catch-water drain, formed above the Road, and in bogs and wet swamps, parallel or counter drains sunk to the depth above mentioned, and at a parallel distance of 30 to 50 feet from the fence.

7. No more water should be led to any gullet or cross drain than can be conveyed safely through. The *bog-drains* should be scoured

and deepened repeatedly until they attain permanently the intended dimensions.

8. Where the water is not freely discharged by the side drains, tail drains must be cut to the nearest rivulet or other proper out fall.

RETAINING AND PARAPET WALLS.

1. The external face of the Retaining Walls should have a curved batter of 3 inches to each foot in height, and the back may be parallel thereto. The thickness shall be 2½ feet when the height is less than 10 feet, and in all other cases the thickness shall be *one-fourth* of the height. *Retaining walls* not exceeding 2 feet in height, may be formed of sods of fifteen inches in thickness; where they exceed that height they are to be of dry masonry well bedded and bonded and joints carefully broken. The inside face of the wall to be made with projecting stones, the beds to be perpendicular to the curve and the foundation cut into steps. An offset of 8 inches should be left at front of the footing course.

2. Where such walls are formed along watercourses, the foundations should be at least twelve inches below the bottom, and paved along the toe for a breadth of 18 inches.

3. The stuff to be filled in behind should be firmly rammed and consolidated before gravel or other road materials be applied.

4. All *parapet walls* should be 20 inches thick and 3½ feet high, built of lime mortar masonry in regular 14 inch courses. The top course or coping should be semicircular, having thorough bonds at every three feet, and not to have more than two stones in any instance in the breadth—the circular form may be given the stones with the mason's hammer.

GRAVELLING.

1. The upper crust of the *Road* should be made with gravel or broken stones, and not to be applied until the forming is quite consolidated and completed.

2. Where gravel is used for metalling it should be of a clean description, free from loam

or fine sand, and of such size as will pass through a ring of one inch diameter.

3. Where broken stones are used they should be of such size as may pass through a ring of 1½ inch diameter, and of the best description to be had within three miles of the places where applied.

4. The road materials should be spread evenly in two layers to a depth of eight inches in the centre and four inches on the sides.

5. Slate Clay, or other soft stone should not be used; no clay or earth should be mixed with the materials by way of blending.

General Directions for Repairing Roads.

1. Where the depth of the materials of a Road exceeds eight inches in the centre and four on the sides, no new metalling will be necessary for its repairs; in this instance it will be sufficient to pick up the projecting stones as well as all irregularities of surface, and have

them broken and spread again, and the whole raked over so as to form a smooth, even and regular surface.

2. All sudden checks and cross wavings should by cutting and filling be brought to uniform inclinations, and when the *Formation* of the Roadway is so finished, the centre should be higher than the sides, so as throughout the entire length to have a regular fall for the rain water, not less than *one*, nor more than *two* inches in the *yard* from the centre to the sides, where Water Tables should be made to convey the surface water into the Dykes or Grips and from which again outlets must be made so that the Grips may run dry.

3. Where the sides of the road must be cut, to give the surface the required convexity, or to form Water Tables, their edges should be perfectly straight or uniformly curved, according as the direction of the road may be either straight or curved. The sides of the Water Tables should not fall suddenly like a Trench, but

might have a uniform fall to its extreme edge rather steeper than the cross-fall of the roadway and gradually sloping into it.

4. Sufficient covered Drains and Sewers should be made in all places where necessary to discharge stagnant waters, and the road throughout its entire length perfectly drained before the application of metalling. Open surface drains or paved channels across the roadway ought not in any instance be adopted.

5. The full breadth of the Roadway between the fences should be repaired.

6. The materials for repairs should be of hard screened Gravel or Broken Stone, free from sand or earth, and of such size as will freely pass through a ring of *one and one half inches diameter*. No larger sized stone than this should be used, and as far as practicable let all be of an equal size. They should be perfectly free from sand, mud, earth, clay, slate or friable substance. The materials ought to be of equal hardness. They should be perfectly free from sand, mud, earth,

clay, slate or friable substance. The materials ought to be of a hard description, and should be applied but partially during dry seasons—moist weather will be found best for extensive repairs. In spreading the Materials, the stones should be laid on in sheets one stone in thickness as closely as possible, and to within two feet of the Water Tables on each side, not allowing any to be scattered, having the sides perfectly straight where the road is direct, and gently curved where it bends. The surface of the roadway should be perfectly cleaned from mud or dust before the metalling is applied. Gravel or broken stones smaller than what may pass through a half inch ring should not be allowed.

7. The surface of the road should be partially loosened with a pickaxe around the edges of freshly applied metalling, which will have the effect of readily uniting the new with the old surface.

8. It should be required to clear, open and repair all Sewers and Gullets upon the road, as

well as to make new Drains for tapping springs or other lodgments of water affecting the road.

9. The overseer should not allow nuisances of any kind, on any part of the road-way, such as heaps of dung, clay, stones, &c. or pigs, or digging the *dykes or Water Tables*, or encroachments of private roads, houses, fences, &c. or heaping or breaking stones on the travellable surface or nuisances of any sort whatever.

10. The overseer should also keep all sewers and gullets repaired, clear and open; the surface of the road and foot-ways (if any) at all times in thorough repair; and all walls, fences and other works in proper order.

The excellence of a road is generally estimated by the gentleness of its planes of inclination, and the inclination of a plane is usually expressed in aliquot parts of its base—for instance, if a plane should rise or fall one foot measured perpendicularly, at the end of Thirty feet measured horizontally, the rate of inclination is said to be

1 in 30—and again, if a plane should rise or fall one foot measured perpendicularly, at the end of Fifty feet measured horizontally, the rate of inclination is said to be 1 in 50, and so on.

The following rates of inclinations corresponding with angles of elevation and depression have been compiled from tables of Natural Tangents. They may afford facility in laying out planes of inclination upon new roads, and upon improvements on old lines. A good six-inch theodolite is best adapted for this purpose—with it, angles of elevation or depression may be taken to every minute, which will be found sufficiently accurate for making common roads.

These tables shew the angles for all planes whether acclivities or declivities ranging between 1 in 3438 and 1 in 8⅛ and by a simple inspection of them without any calculation, the *angle of inclination* on ascending and descending planes may be found if the rate of inclination is known, and *vice versa.*

TABLE.

Minutes.	DEGREES.							Minutes.
	0°	1°	2°	3°	4°	5°	6°	
	1 foot in	1 foot in	1 foot in	1 foot in	1 foot in	1 foot in	1 foot in	
0	Level.	57.3	28.6	19.1	14.3	11.4	9.51	0
1	3438	56.4	28.4	19.0	14.2	11.4	9.49	1
2	1719	55.4	28.2	18.9	14.2	11.4	9.46	2
3	1146	54.6	27.9	18.8	14.1	11.3	9.44	3
4	859	53.7	27.7	18.7	14.1	11.3	9.41	4
5	688	52.9	27.6	18.6	14.0	11.2	9.38	5
6	573	52.1	27.3	18.5	14.0	11.2	9.36	6
7	491	51.3	27.1	18.4	13.9	11.2	9.33	7
8	430	50.5	26.8	18.3	13.8	11.1	9.31	8
9	382	49.8	26.6	18.2	13.8	11.1	9.28	9
10	344	49.1	26.4	18.1	13.7	11.1	9.26	10
11	313	48.4	26.2	18.0	13.7	11.0	9.23	11
12	286	47.7	26.0	17.9	13.6	11.0	9.21	12
13	264	47.1	25.8	17.8	13.6	11.0	9.18	13
14	246	46.4	25.6	17.7	13.5	10.9	9.16	14
15	229	45.8	25.5	17.6	13.5	10.9	9.13	15
16	215	45.2	25.3	17.5	13.4	10.8	9.11	16
17	202	44.6	25.1	17.4	13.4	10.8	9.08	17
18	191	44.1	24.9	17.3	13.3	10.8	9.06	18
19	181	43.5	24.7	17.3	13.2	10.7	9.03	19
20	172	43.0	24.5	17.2	13.2	10.7	9.01	20
21	164	42.4	24.4	17.1	13.1	10.7	8.99	21
22	156	41.9	24.2	17.0	13.1	10.6	8.96	22
23	149	41.4	24.0	16.9	13.0	10.6	8.94	23
24	143	40.9	23.9	16.8	13.0	10.6	8.92	24
25	137½	40.4	23.7	16.7	12.9	10.5	8.89	25
26	132	40.0	23.5	16.7	12.9	10.5	8.87	26
27	127	39.5	23.4	16.6	12.8	10.5	8.85	27
28	123	39.1	23.2	16.5	12.8	10.4	8.82	28
29	118½	38.6	23.1	16.4	12.8	10.4	8.80	29

TABLE (CONTINUED.)

Minutes.	DEGREES.							Minutes.
	0°	1°	2°	3°	4°	5°	6°	
	1 foot in	1 foot in	1 foot in	1 foot in	1 foot in	1 foot in	1 foot in	
30	115	38.2	22.9	16.3	12.7	10.4	8.78	30
31	111	37.8	22.7	16.3	12.7	10.4	8.75	31
32	107	37.4	22.6	16.2	12.6	10.3	8.73	32
33	104	37.0	22.5	16.1	12.6	10.3	8.71	33
34	101	36.6	22.3	16.0	12.5	10.3	8.69	34
35	98.2	36.2	22.2	16.0	12.5	10.2	8.66	35
36	95.5	35.8	22.0	15.9	12.4	10.2	8.64	36
37	92.9	35.4	21.9	15.8	12.4	10.2	8.62	37
38	90.5	35.1	21.7	15.7	12.3	10.1	8.60	38
39	88.1	34.7	21.6	15.7	12.3	10.1	8.58	39
40	85.9	34.4	21.5	15.6	12.3	10.1	8.56	40
41	83.8	34.0	21.3	15.5	12.2	10.0	8.53	41
42	81.8	33.7	21.2	15.5	12.2	10.0	8.51	42
43	79.9	33.4	21.1	15.4	12.1	10.0	8.49	43
44	78.1	33.0	20.9	15.3	12.1	10.0	8.47	44
45	76.4	32.7	20.8	15.3	12.0	9.9	8.45	45
46	74.7	32.4	20.7	15.2	12.0	9.9	8.43	46
47	73.1	32.1	20.6	15.1	12.9	9.9	8.41	47
48	71.6	31.8	20.4	15.1	11.9	9.8	8.39	48
49	70.2	31.5	20.3	15.0	11.9	9.8	8.37	49
50	68.8	31.2	20.2	14.9	11.8	9.8	8.34	50
51	67.4	31.0	20.1	14.9	11.8	9.8	8.32	51
52	66.1	30.7	20.0	14.8	11.7	9.7	8.30	52
53	64.9	30.4	19.9	14.7	11.7	9.7	8.28	53
54	63.7	30.1	19.7	14.7	11.7	9.7	8.26	54
55	62.5	29.9	19.6	14.6	11.6	9.6	8.24	55
56	61.4	29.6	19.5	14.5	11.6	9.6	8.22	56
57	60.3	29.4	19.4	14.5	11.5	9.6	8.20	57
58	59.3	29.1	19.3	14.4	11.5	9.6	8.18	58
59	58.3	28.9	19.2	14.4	11.5	9.5	8.16	59

In the foregoing Tables the top is marked in degrees from 0° to 6° and the two marginal side columns in minutes from 0' to 59'. Under the degrees are columns marked on top "1 foot in" which contain the lengths of base lines corresponding with one foot rise for each angle of inclination. The use of the tables may be illustrated by two examples—viz. If the observed angle of inclination be 1 degree and 20 minutes, then in the column under 1 degree and opposite to 20 minutes on the side is 43 showing the inclination to be 1 in 43. If the rate of inclination be given, say 1 in 33 to ascertain the angle corresponding thereto, then by examining the column headed "1 foot in" we find 33 under 1 degree and opposite to 44 minutes, shewing that the angle 1 degree 44 minutes corresponds with 1 in 33 rate of inclination.

The tables embrace all planes of inclination between 1 in 8 and 1 in 3438 which will be found sufficiently extensive for practical purposes.

ROAD DRAINAGE.

CHAPTER IV.

OF the many things to be attended to for the effectual preservation of the public roads there is none more necessary than Drainage. This important process divides itself into two sorts, *subsoil-draining* and *surface-draining*.

By the one the water that filters through the the ground being cut off is prevented from mixing with the subsoil of the roadway for a certain depth below the crust of surface metalling. By the other the water that falls on the surface of the covering crust is conveyed away into a sufficient discharging channel.

The first or subsoil drainage makes the ground tenacious and firm. It is effected chiefly by sinking dykes along both sides of the roadway to a depth of about three feet below it, with a bottom having a gentle fall and issuing into the most convenient natural channel such as a stream or river. When such dykes or drains are open they should invariably be made on the *field* side of the road fence, but if covered they may be made on the *road* side: in either case they should be made as close to the road fences as possible and to ensure permanency the sides should have a sufficient slope varying according to the tenacity of the soil. When open side drains are made through cultivated firm land, a breadth of five feet at top, sloping on both sides to eighteen inches at bottom will be found sufficient. But the dimensions must be entirely regulated by the nature of the soil to be drained and the quantity of water to be discharged. The dimensions stated will however be found sufficient under most circumstances.

The second or surface drainage is effected by forming the road crust into a convex figure, having the middle slightly elevated above the *sides*, which latter from their receiving the surface water are usually called *water-tables*. The water flows along them to openings made under the road-fences at convenient intervals and is discharged into the deep subsoil drains or grips alluded to.—Water-tables should invariably be paved when their declivity is steeper than one in Thirty.

In wet springy ground it often becomes necessary to make transverse drains across the roadway to relieve the subsoil from the water with which it is surcharged; but such drains must be either covered with thick flagging or filled with stone.

Effectual drainage is of the first importance for road making and for maintaining a road-way in proper condition. It is impossible to preserve the surface of a road without a thorough draining: because when the subsoil is moist or saturated with water, the particles of which it is composed are easily moved among each other, lose all tenacity and become quite incapable of sustaining the road crust which is pressed through by the slightest weight.

Some variety of opinion has occasionally existed even amongst the most eminent road Engineers as to the best mode of securing a firm crust of metalling, but all concur in asserting that without effectual drainage no effort or expense will avail towards obtaining a good roadway. Whatever be the quantity of broken stone metalling spread upon an undrained road instead of being agglutinated and formed into one consistent crust it will continually sink through the wet foundation or subsoil which will soon work up through the stones, filling all the interstices between them. The earth and stones being thus mixed, the stones are easily worked amongst one another, and what with a little pressure from the superincumbent load of cars and carriages and a little moist weather, the entire soon becomes one mass of mud, or else is converted into clouds of dust as the season may be.

The mere sinking of side grips and elevating the centre part of a road will not always be sufficient for a proper drainage. The space between the grips forming the bottom of the roadway is frequently so saturated with water, as to require a considerable length of drains to draw it off, and such drains require particular care in their formation and covering, having to sustain the road crust with the weight of the over-passing vehicles.

There are many species of covered drains of which the principal for the purpose of road drainage are, broken stone drains, flagged drains, barrel and tile drains, and bog drains.

The three first, if they be only well executed, are fully equal to any pressure from above that a reasonable amount of traffic may require; but bog drains are unsuited to any road purpose save and except that of lateral drainage.

Broken stone drains are recommended not only by their durability, but furthermore on the ground of economy they are preferable to any other description of covered sewer for draining the substrata of roads, inasmuch as the necessary materials can be had at the cheapest rate, with the greatest facility and in the greatest abundance in every locality.

Fig. 4 on the annexed plates represents the cross section of a broken stone drain. The drain should be sunk to a depth of thirty inches below the surface of the road with a perpendicular altitude of twelve inches, a breadth of thirteen inches at top narrowing regularly to three at bottom, a longitudinal current or fall of one inch in twenty feet and an interval of eighteen inches between its uppermost broken stones and the metalling of the road-way. It would be the best plan to fill up this space of eighteen inches betwixt the drain and the crust of the road with stone, if convenient; otherwise let it be well packed with the material cast up in excavating the drain. The broken stone forming the drain should be of a size not more than three inches square and, as already observed, it should be filled with them to a height of twelve inches. The dimensions here stated will be generally found sufficient, yet much must be left to the judgment of the overseer who will often find it necessary to vary the dimensions according to circumstances. Broken stone drains of the dimensions specified can be executed in most parts of Ireland for six-pence the statute perch of 16½ feet, including all expenses except procuring the stone, which must vary with their convenience. Such drains it is ascertained work for years without being choked or needing repair. The broken stones bearing upon one another form a perfect support for the roadway and at the same time leave sufficient openings between their angular projections to allow the drainage water to flow off. They also suffice for carrying off all other waters unless a stream or some considerable quantity has to be discharged, for which purpose flagged sewers must be constructed.

Flagged sewers intended to discharge the accumulated waters of the road grips and other drains, are placed at the lowest practicable levels. Instead of cemented mason-work, let the sides be built with dry walling, which as being cheaper deserves the preference on a principle of economy and also because the open interstices afford an effectual drainage without injuring the stability of the work. The dimensions of these drains must within certain limits be determined by the quantity of water it may be required to discharge. They ought to be at least eight inches wide by twelve deep, the covering stones not less than four inches thick with a bearing of four inches on each side wall and at least twelve inches below the road-metalling. The side walls and covering stones may be of rubble stone or rough flag stones, and it is all the better if the joints of the covering flags be counter flagged to prevent the bearing soil from washing through or working into the sewers. Should it be required to carry off a large quantity of water or should the slope of the drain be abrupt the bottom must be protected from the effects of erosion by a flagging or rough pavement. When the inclination of the drain is more than one foot in twenty let the bottom be flagged and formed into steps each at most six inches high which will check the flow of the current and prevent it from acquiring an injuriously accelerated velocity. The flags will be firmer in their places and the whole work more permanent if they tail under the side walls. Drains of this description, not paved or flagged at bottom, and in the vicinity of quarries of building stone, may be executed for nine pence the lineal or running perch: twelve pence will be an adequate price with paved or roughly flagged bottoms.

The following table exhibits at one view the different velocities at which currents of water have a disturbing force sufficient to dislodge and carry away different substances over which they pass in their course.

Velocity of Water per second. FEET.	INCHES.	Bottom on which it acts.
0	3	Mud begins to yield.
0	6	Clay carried off.
1	0	Sand carried off.
2	0	Gravel carried away.
3	0	Pebbles disturbed.
4	0	Large Pebbles carried away.
5	0	Bolders and Schistus Rock torn up.

Besides the covered drains described, *mitre drains* are used on steep acclivities and in deep cuttings, not differing from the others in mode of construction, but resembling the letter V in their longitudinal direction, the angular point being in the centre of the road and pointing in the direction of the ascent. The acuteness of the angle of meeting of the sides must depend upon the fall in the roadway; the steeper that fall the wider the angle should be, by which means the slope of the bottom of the drain will be reduced.

To preserve the bottom from the injurious action of the running water, it should not be steeper than one in one hundred, or about one inch fall for three yards in length. Mitre-drains may be constructed entirely of broken stones, as before described, or they may be covered sewers according to the quantity of water to be discharged through them; but as their chief use consists in relieving the subsoil of the roadway from excessive moisture, the broken stone will in most cases answer best.

Such drains placed at distances of fifty or sixty feet from one another, will render the drainage complete, it being always supposed as a condition essentially necessary that they have a free discharge into the main drains.

Barrel and Tile drains are made with tubes of baked earth from two to three feet long, where such materials can be conveniently procured as a substitute for the broken stones or flags. But not possessing any decided advantages over the other species of drains and being withal more expensive, it is seldom that Barrel and tile drains are used by road makers. Fig. 5 represents this sort of drain.

Bog drains, from the softness of the soil through which they are made, require some care in their construction. If laid down and formed with judgment equal to the facility of their construction, they would prove permanent enough for lateral drainage and by no means liable to the disturbance which the softness of the soil might lead one to apprehend. Bog drains should be made deeper than drains through other soils on account of the fibrous composition of bogs, which causes moisture to be attracted to their surface from greater depths than in other soils. The fibres are capillary tubes the attraction of which holds water at a considerable height above the adjoining drains.

Open drains require to be frequently widened and deepened before they acquire a permanent dimensions. Very soon after sinking them the sides will collapse and the bottom swell upwards nor is it possible to counteract this tendency to change of form and dimension any otherwise than by repeated sinking and widening.

Covered Bog drains on the contrary if judiciously executed will be found more permanent. Of necessity they must be small in dimension and therefore unsuited for main drains; yet they answer well for draining the space or ground immediately beyond the roadway and lying close by the Grips or open side drains into which the covered drains discharge. They should be made in parrallel directions one to the other, and at distances of fifty feet or less according to the wetness of the ground. Fig. 6 is a cross section of this sort of drain in which the lower part a, b, c, d, represents the permanent opening or channel for receiving and discharging the water, about three inches wide at bottom and seven inches at top. The larger space marked e, f, g, h, is first excavated eighteen inches in breadth and two feet in depth, and the top or surface-sod for a thickness of six inches carefully pared off is laid by; for it is afterwards to be used as a covering for the permanent drain, upon the shoulders of which it is to be placed with the grass side down. The drain being formed and covered, the space over the covering sod is then filled in with the material procured in the excavation.

Drains of this description can be made for two pence the lineal perch and never have been found to break down or choke. They are but little used in road work but most extensively in the reclaiming of Bogs. When a road passes over a bog soil and it is deemed necessary to drain the ground at each side of the road to any extent these drains will be of great use.

The systems of drainage adapted to land reclamation are in general applicable in respect to road draining also except only that more solid drains are requisite in the latter case.

In excavating the sites of walled drains, there will commonly be no need of widening the excavation beyond the intended ope and side linings. Covered sewers with opes or water-ways of from eight to eighteen inches square require covering flags four inches thick: those having opes greater than eighteen inches and under two feet require covering flags five inches thick and those with an ope measuring between two feet and thirty inches must have covering flags six inches thick. A width of from two feet to thirty inches may be stated as in general the maximum width of drains. If a single ope of larger dimensions should be deemed necessary, arching is preferable to flagged gullets.

When a spring appears in the surface of a road, the common mode of tapping it is to cut a surface drain a few inches deep from the spring to the adjacent water-table or side drain, and fill this cut with small stones. But the insufficiency of this remedy will soon be manifested upon the consolidation of the stones, for then the spring will again make its appearance; and though it may be stanched by repeating the remedy, it will reappear again and again in the same place, or, which comes to the same thing, it will make a vent elsewhere. After much and ineffectual trouble the road-experimenter will be convinced of the inadequacy of every attempt short of general and extensive drainage to guard against such sudden burstings.

Drains of every description notwithstanding the employment of all due care in their construction, are liable to derangement from the deposition of matter and other causes impeding the free discharge of the water.

Any such derangement is soon and easily discovered, because the pent up water readily forces its way through the drain and road-crust to the surface, where its presence may be at once detected by the dampish appearance of the surrounding part.

To apply a remedy the drain must be opened upwards at the distance of a few feet below the place where the moisture appears. The dryness of the part of the drain beneath will at once indicate that the water had not passed through; and it must be ripped and cleared out until at each end of the part so taken up, the water is observed to flow freely through. The drain should then be re-made and the road materials firmly packed down upon it, care being taken not to allow the part repaired to rise above the level of the adjacent road surface, a practice but too common and attended with no small inconvenience.

Prompt attention to the removal of defects in the drainage will preserve a road and save expense, as on the contrary neglect in this particular will speedily cause a total break up of the road crust and impose the necessity of increased expense for the repair.

The Author's attention was directed a few years since to a portion of the *Red Strand road* in the western part of the County of Cork, upon which upwards of 50,000 tons of sea sand were annually conveyed. This road though frequently repaired had been nevertheless but little the better for the frequent mendings and makings insomuch that many persons deemed it a thing impossible to get rid of this perversely bad road any otherwise than by its total disuse and the construction of a new road in a different situation.

Upon examination it appeared that imperfect drainage more than anything else was the cause of its inveterate badness. It lay along a valley and was commanded on the upper side by an extensive slope of wet springy land which completely saturated the substratum through which the crust of materials laid on were sure to sink almost as soon as they were applied. The cause of the defect being obvious, we had an open wide drain sunk upon the hill side parallel with the road and three feet below its surface, together with a second one below the road but of smaller dimensions. These drains received all the waters that could act with injurious effect as well those on the surface of the high lands commanding the road as also those of the subsoil which were discharged by cutting open the veins of the lower strata previously choked up to a depth of three feet. From the bottom of these drains others eighteen inches square filled with broken stones were made across the roadway at every fifty feet, and a free discharge was provided from the main drain into a natural stream running close below the road. The surface was then coated over with two layers each three inches thick of broken stones, every stone of a size to pass through an *inch and half* ring; and although the intercourse upon this road has been much increased, yet so effectual was the drainage and, owing to the drainage, the repair also, that the surface is since maintained in excellent condition at a reduced rate per annum.

In a thousand different instances occurring in the course of our professional engagements the foregoing plan was adopted and invariably found to be attended with the like result.

Figs. 7 and 8 on the annexed plate are cross sections of the road alluded to in the preceding observations, Figure 7 representing it before and Figure 8 after drainage.

Surface Drainage of roads becomes our next subject of consideration. Roads are generally of a convex figure on their cross section with the view of facilitating the surface drainage: a concave figure has also had its advocates as one well adapted to the purpose of drainage; and others again would be for dividing the surface into two parallel convex carriage ways with a depressed channel in the middle to carry off the water.

With this diversity of opinion each contends for it that his peculiar plan is the best for the effectual discharge of the surface waters; and in their zeal for their respective opinions they many of them forget that no lateral fall safe for carriages could of itself, at least in ordinary cases drain off a roadway partially covered with mud. The wheel-tracks made in a surface even partially coated with mud will in great measure neutralize the advantage of a cross-fall. On this account gentle longitudinal inclinations have been recommended, but notwithstanding, an irregularity, how trifling soever it may be, or ever so small a quantity of dirt on the road will obstruct the free discharge of the water. The action of the sun and wind serves more to relieve a road from surface water than any artificial contrivance and, therefore, high buildings, trees, and every thing that impedes the action of the wind or keeps off the sun are injurious to a road.

Some persons wishing to subject roads to a cleansing process would have them periodically flooded in order to wash away all extraneous matter. This is liable to objection for more reasons than the general impracticability of the process. What can be accomplished in the way of surface-drainage by the convex form of the road is but of small account: indeed it can do little else than prevent the roads becoming a basin of still water.

Stone drain holes should be made in size about 8 inches square under the side fences and about two inches under the level of the water tables from whence there will be a free discharge into the grips. These drain-holes should not be farther apart than 100 feet, and where the longitudinal inclination of the road is sudden they should be at smaller distances.

It is necessary now and then to turn off the water from the water-tables that the accelerated motion acquired by the fall may not cut up the surface of the water-tables. Where the surface water cannot be discharged from the water tables at short intervals, as for instance where a road is formed through deep excavations, it will be necessary to pave the water-tables so as to render them proof against the erosive action of the current.

The simplest sort of drain for discharging surface water is that made with four flag-stones four-inch-thick one on each side and one at top and bottom forming an ope of eight inches square or thereabout. When there is a footway between the water-table and the grip the drain must be continued under the footway, and the outer or curb-stone of the path perforated by a square or round hole large enough to let off the water into the drain.

ROAD MATERIALS.

CHAPTER V.

STONE is the material used in making and repairing the surface or upper crust of ordinary roads. In Holland hard burnt bricks are largely used as a substitute for stone. In London *wood* is extensively employed for the repairs of the principal streets, but is too expensive for ordinary roads ever to supersede the use of stone. Iron and wood combined are the most approved materials now used in forming the upper works of Railways, but as the observations following confine themselves to the exclusive province of treating of common roads, they will refer to the different sorts of stone adapted to the formation and repairs of such roads only.

An accurate knowledge of the physical and chemical properties of different sorts of stone materials would be of very great importance for making and surface repairs. The resistance which material offers to friction and shocks, the changes which it undergoes from exposure to the weather, its capability of absorbing water, its toughness and the time and labor required in breaking it for road covering—these are the most essential considerations in determining the suitableness of stone for repairing roads and a knowledge of them would manifestly be of the utmost utility. A hard material will best resist the shocks and attrition caused by heavy loads. Close grained heavy stone will absorb least water whence it is the best for resisting the action of frost. It is a property of frost familiar to most persons that it expands the bulk of water and by this expansion of the frozen water it is able to burst stone into small fragments, which being subjected to the action of moisture after frost are converted into a mass of mud and sand.

For obviating this tendency of a road to go to ruin in time of frost heavy stone of a close texture will be found the best adapted as having the smallest capacity of absorbing water.

The stones commonly used for road making and road repairs may be arranged in three classes.

1st. *Siliceons* of which silex or sand forms the principal part.

2nd. *Argillaceous* of which argil or earth forms the chief part.

3rd. *Calcareous* of which lime is the base.

SILICEOUS STONES.

Under this head may be classed the several varieties of *Granite, Gneiss, Sienite, Red and Grey Sand Stone, Free Stone, and Buhr or Mill-Stone.*

The species of stone belonging to this class are suited for road metalling in different degrees. *Granite, Gneiss,* and *Sienite,* which exhibit a striking similarity in appearance and physical properties, may be said to differ in little else than their constituent elements. The fracture of Granite presents a homogeneous and compact appearance, whilst in Gneiss the particles are distributed in layers giving the stone a laminated texture. From the liability to split in the direction of the laminæ, Gneiss is not so well suited to the formation of a surface crust intended for heavy loads and considerable intercourse. However the excellence of this material in other respects is such that it should not be readily objected to, particularly as the laminæ are united by a strong natural cement.

Granite appears to have been the name generally applied by antiquarians to every granular stone used in architecture and statuary; nor it was not until very lately that it was distinguished as a particular species of mountain rock. Granite is composed of granes or concretions of felspar quartz and mica intimately joined but without any basis or ground. These parts vary in quantity, so that sometimes one predominates, sometimes another, and often two of them. Felspar is generally the predominating as mica is the is the least considerable ingredient of the rock. In some varieties the quartz is wanting, in others the mica; and such varieties are distinguished by appropriated names. These minute distinctions and sub-divisions however are unnecessary inasmuch as they serve only to mark varieties of the same species. The mica sometimes decomposes by exposure to the atmosphere and the felspar is occasionally found of an earthy nature. Both these descriptions of stone will be found inferior as a road material. Granite having its constituent parts chrystallized affords the best road metalling. Quartz to the eye is transparent and of a glistening white colour. Felspar varying in colour is whitish or reddish, is less transparent than quartz and puts on a dull white appearance when exposed to the action of the weather. Mica is found in scales of a glistening dark hue when imbedded in the stone, but when detached nearly as transparent as glass for which it is often used as a substitute. The best quality of stone will be that in which the component particles are finest and most uniformly distributed. If the quartz be distributed in large grains the stone will be brittle.

SIENITE.

Sienite is a granite in which the mica is generally replaced by hornblende, some varieties however also containing mica. Werner says it is a granular aggregated rock composed of felspar and hornblende with occasional scales of mica and grains of quartz. It is named from *Syene* in Upper Egypt, where the ancients quarried it in blocks of great magnitude; and specimens of sculpture executed in this stone over 3000 years ago and exposed ever since to the action of the atmosphere remain to this day and attest the great durability of the material. The particles of hornblende of which sienite is chiefly composed, are easily distinguished by the greenish shade which the stone assumes when moistened. It forms an excellent road material.

SAND STONES.

Sand Stone as well as *Free Stone* is composed chiefly of fine particles of quartz united by an argillaceous or calcareous cement. It also occurs in the form of conglomerate and breccia. The grains in the sand stone are principally quartz with occasional intermixture of felspar, flinty slate and scales of mica; the roundish and angular masses in the conglomerate and the breccia are frequently of quartz, or granite, gneiss, mica slate, clay slate, sienite, quartz rock, &c. The basis or ground is generally a ferruginous clay, or it is composed of smaller particles of quartz or felspar as is often the case in the conglomerates and breccias. The basis is sometimes highly impregnated with silica, and then it is a very hard and excellent road material.

Some compact varieties of indurated sand stone are composed chiefly of pure silex and make good road metalling; but when other substances are mixed in large proportions with the particles of silex, the stone acquires a loose and porous texture, imbibes a large quantity of water, disintegrates by the action of frost, and once reduced to a state of disintegration crumbles into dust under the pressure of the lightest load.

Sand Stones in general are dry and brittle, are easily broken, and under the wheels of loaded carriages are soon converted into a sandy powder. Flint pebbles freed from earthy matter and broken into *angular* pieces make excellent metalling. A soft description of flints is occasionally to be found which should not be used on roads where much intercourse is carried on.

Buhr or Mill Stone from its hardness would prove a good material for a lower stratum of metalling, but is not so well suited for surface repairs of roads.

Extensive formations of Siliceous rocks are to be found overspreading every known country of the world. Granite and Sienite abound in these countries in the Grampian hills, Aberdeen, Inverness, Cumberland, Cornwall, Wicklow, Carlow, Galway, and Donegal. They have been discovered in every latitude from the Polar regions of Europe to the Mediterranean Sea, in Finland, in the Hartz, in Saxony, in the Alps of Switzerland, in Austria, in the Carpathean mountains, in the mountains of Auvergne and in the Pyrenees. Asia, Africa and America wherever explored are also known to contain them in large quantity.

ARGILLACEOUS STONES.

Under this head may be classed all *Slate Stones*, *Trap-rocks* consisting of *Green Stone* or *Basalt*, *Graywacke* and *Graywacke Slate*. Of these the green stone or Basalt is in general a good road material, but the others not so well adapted to the purpose.

Greenstone or basalt though of an earthy basis is very strong and hard, but from the oxidation of the iron which forms a large ingredient in its composition it is apt to break into scales and for this reason does not constitute so very good a road metal. In the natural bed it is often found so hard as to make it impossible to detach it from its place by any other means than blasting, yet exposure to the joint action of air and water softens and disintegrates it into small particles. The varieties most perfectly vitrified are the best for road work—*Lavas* nearly resemble basalt, some of them decompose rapidly, whilst others resist the action of the atmosphere for centuries without undergoing any sensible change.

Graywacke partakes more of the quality of sand stone being most part composed of the fragments of other minerals in a granular state united by an argillaceous cement. It consists chiefly of angular or other portions of quartz, felspar, and clay slate, united by a basis or ground of the nature of clay slate, which is often largely impregnated with silica and by this means gives the mass a considerable degree of hardness. The imbedded particles vary in size, seldom however exceeding a few inches in breadth and thickness. When the imbedded portions are very small the rock assumes a slaty structure and forms the *Graywacke slate.* Either variety forms but an inferior road material.

When the grains almost entirely disappear from this rock it comes under the denomination of *clay slate.* Clay slate is for the most part very soft, in so much that the joint effect of the weather and vehicles will soon reduce it to a state of clammy puddle offering great resistance to draught. It is consequently unfit for road repairs.

Greywacke and *Clay Slate* abound in the British Isles, in Europe generally and in North and South America. It is to be found in abundance in all the mountain ranges south of the Firth of Forth and is the principal formation to be met with in mountains of the South West of Cork, Wexford, Louth, Armagh, Monaghan and Down.

CALCAREOUS STONES.

Calcareous Stone, known more generally as *Lime Stone,* is composed of lime, carbonic acid and water in small quantity combined with metallic oxides.* The general properties of lime stone are so well known and so easily distinguished as to need but little elucidation, with nitric acid it effervesces strongly, and by exposure to a red heat the carbonic acid and water are driven off leaving that pure lime of commerce with which every person is acquainted.

This species of stone is very common and presents numerous varieties, several of them remarkable for strength, hardness and durability, and others are soft and liable to decay. They are classified under too general divisions, the *granular* and the *compact.*

The Granular presents the appearance of an aggregation of grains some fine and others coarse: the compact exhibits a uniform texture without any indication of grains, being quite earthy in appearance.

The granular affords a good road material able to withstand the effects of wear and capable of bearing much work without yielding in any considerable degree to its action.

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* Oxides are combinations of metals with oxygen; rust is an oxide of iron.

The Compact Lime Stone deserves attention and is chiefly used as a building stone. It furnishes a great variety of marbles bearing a high polish.

Limestone generally having a great affinity for water and imbibing it in large quantities is soon converted into mud by the action of wheel-carriages. When it is saturated with water and then frozen the injurious consequences are at once seen in the crumbling of the stone and general break up of the road surface caused by the expansion of the water.

Ireland and England supply each variety of this stone in great abundance; indeed, it constitutes fully one half the superficial extent of the former. Scotland likewise supplies it in parts of Lanarkshire, Fifeshire, Dumfriesshire, &c. On the Continent it is found in extensive ranges of mountains, stretching through the Netherlands, France, Italy, Poland, Russia, &c.

It forms a portion of Mount Jura, the Alps, the Appenines and the Pyrenees. It has also been found in great ranges in Asia, Africa, and America.

The upper beds of Lime-stone strata are generally much decomposed from the combined action of moisture and the atmosphere, for which reason they are not by any means a good road material. The earthy limestones are commonly bad and unless in cases of indispensable necessity should not be employed in making or repairing roads, their chief defect arising from the ready absorption of water which renders it quite easy for the wheels of vehicles to convert them into mud in an incredibly short space of time. Limestone however does not want useful properties and should not be lightly condemned as a road-material. In moist weather it agglutinates quickly under partial traffic, though other descriptions of stone will not in the same manner form a compost but will remain in detached lumps, considerably impeding the traction of vehicles and making on the whole but a very disagreeable roadway.

To whatever general classes we may reduce the various descriptions of stone, whether to Siliceous or Argillaceous, or Calcareous, even those classified together will often be found to have very opposite qualities and may make either very good or very bad road metalling. Any directions therefore for the selection of proper stone must be at best of a general nature, leaving much to the judgment and care of the road maker.

As a general remark it is worthy of observation, that strength, hardness and elasticity are the qualities of stone most required for road repairs, and that whatever material is found to possess any one of these qualities is most commonly found to possess the other two along with it. The external appearance of stone will not always be an accurate criterion whereby to estimate its quality or fitness for road metalling. If the texture be granulated, or chrystaline and compact and the specific gravity considerable, the stone will form a good road metal. But whether of granular or other texture, stone that will crack or contains cavities should not be used such being always brittle, weak, and liable to rapid disintegration. Stones that wear smooth and acquire a polished surface by attrition are unfit for pavements. It is more difficult to ascertain the durability of fresh quarried stone than of stone exposed for some time to the action of the weather. Hence it is that if we would form an accurate judgment in respect to the durability of stone we must look not to quarries but to the sea shore and rocky precipices where the effects of the weather are open to our observation.

One of the most powerful agents in destroying stone is frost, of which the effects are most visible in very porous stones and in those of a slaty and fibrous texture, both of them readily absorbing large quantities of water. In the former frost causes a disintegration or exfoliation at the surface, in the latter it splits the block into several fragments. Stones that absorb much water are manifestly unfit for road making.

Statuary Marble has been found to absorb the 1,300th part of its weight in water.

Siliceous Sand Stone the 276th part.

Craigleith Stone the 63rd part.

Portland Stone the 16th part.

The following Table gives the weight of a cubic foot of different kinds of stone in ounces, together with the weight in lbs. which *crush cubes of one and a half inch,* and will afford correct means of estimating the fitness of different materials for road repairs as respects the power of resisting compression, and that we need scarcely add is always a most important consideration.

COMPRESSION.

MATERIAL.	Weight of a Cubic Foot in Ounces.	lbs. Avordupois to crush Cubes of one and a half inch.
Chalk	2,500	1,127
Brick of a pale red colour	2,085	1,265
Red Brick mean of two trials	2,168	1,817
Yellow face baked Hammersmith paviers	....	2,254
Burnt ditto mean of two trials	....	3,243
Stourbridge or fire brick	....	3,864
Whitby gritstone	2,088	5,328
Derby grit, a red friable sandstone	2,316	7,070
Ditto from another quarry	2,428	9,776
Killaly white free stone, not stratafied.	2,423	10,264
Portland stone	2,428	10,284
Humbie gritstone	2,224	10,371
Craigleith, white freestone	2,452	12,346
Yorkshire paving—with the strata	2,507	12,856
Ditto ditto —against the strata.	2,507	12,856
White statuary marble, not veined	2,760	13,632
Bramlyfall sandstone, near Leeds, with strata	2,506	13,632
Ditto, against the strata	2,506	13,632
Cornish granite	2,662	14,302
Dundee sandstone or Brescia two kinds	2,530	14,918
Craigleith with the strata (gritstone)	2,452	15,560
Devonshire red marble variegated	....	16,712
Compact limestone	2,584	17,354
Penryn granite	2,590	17,400
Peterhead granite, hard close grained.	2,500	18,636
Black compact Limestone—Limerick.	2,598	19,924
Purbec	2,599	20,610
Black Brabant marble	2,697	20,742
Very hard freestone	2.528	21,254
White Italian veined marble	2,726	21,783
Aberdeen granite—blue kind	2,625	24,556
Valentia Slate	2,672	26,656
Dartmoor granite	2,774	27,630
Heytor granite	2,770	31,360
Herm granite, (near Guernsey)	2,754	33,600

EXPENSE OF MAINTAINING ROADS.

CHAPTER VI.

In comparing different systems for maintaining roads the cost of each must form an important element of calculation for the system which combines in the highest degree economy with convenience is obviously entitled to a preference over every other.

The comparative merits of the various systems of road repairs having been discussed in some of the foregoing chapters, it is unnecessary to dwell at more length upon the subject, and we need only remind the reader that the plan of repair with *broken* stones or *gravel* is the one most highly recommended not only on the score of economy but also because it is at once the simplest and the easiest mode of repair. Assuming this as the best mode, it only remains in this chapter to enter into the practical details of the necessary expense.

Many circumstances affecting the cost of maintaining a road must enter into our calculation, for instance, the amount and nature of the intercourse kept up, the quality and cost of preparing materials, the breadth of the *tiers* of carriage wheels, the climate, &c.—all circumstances far from unimportant, inasmuch as they affect less or more the cost of maintenance.

But of these circumstances the amount of intercourse is in every case the most important. Notwithstanding its paramount importance and the very decided influence it must have in regulating and governing the *expense* of maintaining roads, strange to say, no attempt has hitherto been made to fix with any precision the relation of the one to the other—nor does it require any thing more than the commonest observation to perceive its importance; for if you want to estimate the probable expense of maintaining a given road, what more easy than to see that the first and most material element of your calculation must be the amount of intercourse on the given road. Nevertheless it is a fact that we are furnished with no *data* whereby the ratio which intercourse bears to the expense of maintenance has been accurately determined, though we may avail ourselves of some partial information that may aid us in the solution of the question.

If we except the comparatively few localities through which lines of railways have been projected, public attention has been little, if at all, directed to the amount of traffic on common roads; and even where it has, the inquiry has been conducted for another and far different purpose, and so the information acquired can be turned to but little account in the present case without some further investigation.

In determining the ratio which the expense of maintaining a road bears to the amount of traffic upon it regard must be had to the nature of the traffic, that is, it must for instance be considered whether it be passenger or mercantile traffic, whether the rate of travelling be quick or slow, and so forth.

Calculations and returns were carefully prepared of the amount of intercourse on the present line of common road between Cork and Passage, (a distance of about 6 miles) in the year 1837, when it was proposed to connect these places by Railway. From these calculations and returns we can arrive at some conclusions that will assist in determining the probable expense of maintaining such roads. The intercourse between Cork and Passage is confined almost exclusively to passengers, conveyed in light one horse carriages at a speed averaging seven miles an hour. But upon other roads the vehicles employed are heavier and the rate of speed slower. A comparison fairly estimated between such a road and the Passage road, with its light vehicles and their rapid rate of going, was obviously a good means of arriving at the truth and of solving the problem of the wear of quick as compared with slow moving vehicles. For this end we procured returns of the intercourse on the Red Strand road in the western part of Cork—the traffic upon which is of quite the opposite character to that on the Cork and Passage road, being entirely confined to heavy loads of sea sand for agricultural purposes, conveyed in one horse carts at a speed averaging 2¼ miles an hour.

Both roads have been maintained in nearly a like state of repair by county presentment, and the expense of each has been ascertained from the county records. Here then are clear *data* for instituting a comparison between the expense of maintaining each and the intercourse thereon, and for comparing the effects of different species of traffic and different velocities. The vehicles used in both cases had but two wheels, the breadth of *tier* of the passenger cars being 2¼ inches and of the sand cars 2½ inches.

The present line of road between Cork and Passage is of the ordinary description, made over a dry and firm subsoil. The average daily intercourse has been ascertained to be 250 vehicles carrying 1000 passengers, each vehicle drawn by one horse at a speed of about seven miles an hour. The gross tonnage may therefore be estimated as under—viz.:

250 horses each averaging 8 cwt.	100 tons.
250 light vehicles each averaging 4 cwt.	50 tons.
100 passengers each averaging 1½ cwt.	75 tons.
Gross Tonnage Daily, ...	225
Do. Do. Yearly, . .	82,125

The cost of maintenance for this road according to the fairest* returns from the County Presentment Books is £58 per mile per annum, and referring the above gross tonnage to this gross expense there results an annual expenditure of £1 *per mile* for 1,416 tons of traffic moving at seven miles per hour.

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* From the peculiarity of the law respecting County Presentments which gives a preference to the lowest bidder, the expense of maintaining roads must be liable to some variation, but the sum given in the above estimate may be relied upon as affording the fairest criterion of expense.

In the second case or that of the heavy slow moving machines on the *Red Strand Road*, which is also of the ordinary description, the calculation following is borne out by the most accurate inquiry it was possible to make.

The average daily intercourse may be fairly set down at 135 horses going to the strand empty and returning loaded, with one horse carts moving at 2¼ miles an hour. The gross tonnage in this case may be estimated as under—viz.:

Going to the Strand 135 horses each averaging 9 cwt.	61 tons.
Returning from .. 135 do. do.	61 tons.
Going to the Strand 135 empty carts each averaging 7 cwt.	47 tons.
Returning from .. 135 loads including cart each 20 cwt.	135 tons
Gross Tonnage Daily....	304
Do. Do. Yearly ..	110,960

The cost of maintenance for this road, according to the returns from the County Presentment Books is £16 per mile per annum, and, as in the former case, referring this gross tonnage to the gross expense we shall have an annual expenditure of £1 per mile for 6,935 tons of traffic moving at 2¼ miles the hour.

The foregoing facts enable us to determine the expense of repairs for an ascertained amount of intercourse, and exhibit the wear and tear of quick moving vehicles as compared with slow carriages.

Referring to those data it appears that the gross traffic is 82,125 tons in the first case and 110,960 tons in the second one, whilst the cost of maintenance is 4.9 times greater for the former than the latter; and as the localities are pretty much alike in respect to facilities of repair, climate, &c. the inference is obvious that the rapidity of movement (in this case the only material point of difference) is always a primary circumstance to be considered in estimating the expense of road repairs.

It was given in evidence a few years since before a committee of the House of Lord appointed to inquire into the state of roads in England and Wales, that quick moving vehicles are not so injurious to roads as slow moving vehicles. But how erroneous a conclusion this must be the foregoing *data* clearly evince. Indeed it must appear evident upon a very little reflection that the concussion caused by the horses feet and the vehicle is much greater with a rapid than a slow motion; and the proper and immediate effect of such concussion is to disturb and consequently to wear down the road.

QUALITY OF MATERIALS.

In districts not abounding in the best quality of stone it becomes a matter of the highest importance to determine whether any and what lines of road could be kept in good repair, with the materials supplied in the immediate neighbourhood. The carriage of stone from a remote distance always involves a heavy expense, oftentimes double what it would be if stones were had near the road repaired.

Stones forming an excellent road surface under a limited amount of traffic may be quite unsuited to heavy intercourse by reason of their softness or friability; and it not unfrequently happens particularly in cities and towns where the traffic is very heavy, a good surface cannot be maintained with any but the hardest quality of metalling. Stone is commonly brought at considerable expense from the Island of Guernsey and Scotland and even from Hudson's Bay in North America for repairing roads in the vicinity of London. Such costly materials are used only on the greatest thoroughfares where the *flints* in which the neighbouring counties abound, would almost immediately crumble into dust under the pressure of the traffic maintained upon these roads.

Some very interesting experiments have been made by Mr. Walker, the eminent civil engineer (President of the Institution of Civil Engineers,) npon eight descriptions of stone, seven of them *granite* and one *whinstone*, with the view of ascertaining their relative durability for road metalling. They were laid as *wheel-tracks* on a part of the Commercial road, and the following tabular return exhibits the result of *seventeen months* trial between March 1830 and August 1831.*

Description of Stone.	Place where procured.	Absolute wear in 17 Months.	Time in which one inch would wear down.
		INCHES.	YEARS.
Granite	Guernsey	.06	22½
Granite	Herm (near Guernsey)..	.075	19
Whinstone ..	Budle.................	.082	17⅓
Blue granite..	Peterhead	.131	10⅘
Granite	Heytor	.141	10
Red granite ..	Aberdeen	.159	9
Granite	Dartmoor	.207	6⅘
Blue granite..	Aberdeen	.225	6⅓

It were to be desired that we had an account also of the traffic, and so we should be assisted in fixing the ratio between a tonnage of traffic and the wear of the stone surface.

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* "The Commercial Road Stoneway, on which these experiments were made, consists of two parallel lines of rectangular tramstones, 18 inches wide by a foot deep, and jointed to each other endwise, for the wheels to travel on, with a common street pavement between for the horses. The tramstones subjected to experiment were laid in the

In selecting materials for a road surface the quality or hardness of the stone should always bear a due proportion to the load it may have to sustain. These loads may vary with the sort of machine in general use; for instance, in Ireland, *two wheeled* machines are those commonly employed each weighing from 6 to 8 cwt. and loaded with 22 to 25 cwt. the gross amount of weight being about 30 cwt. In England *four*

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gateway of the Limehouse turnpike, so as of necessity to be exposed to all the heavy traffic *from* the East and West India Docks. A similar set of experiments had previously been made in the same place, but for a shorter period, (little more than four months) with however not very different results, as the following figures corresponding with the column of "*relative losses*," in the foregoing table will shew.

Guernsey........	1.000	Peterhead (blue)..	1.715
Budle	1.040	Aberdeen (red) ..	2.413
Herm	1.156	Aberdeen (blue)..	2.821

All the above stones are granites except the Budle, which is a species of *Whin* from Northumberland, and they were all new pieces in each series of experiments."—*Vol.* 1. *Trans. Inst. Civil Engineers.*

wheeled machines are mostly employed each of which with the load often comes to six tons.

In the former case the gross pressure from each wheel on a given point of the stone surface will be 1,660lbs. in the latter 3,320lbs. These weights act very injuriously upon uneven roads, for when the loaded wheel has reached the summit of each rough or projecting point of the road surface, it acquires a velocity in its descent on the other side, which must of necessity damage the road crust, whence it is manifest that none but the hardest stone should be used on roads of heavy traffic.

The experience of practical men is against the employment of broken stone of larger size than 1½ inch cubic for road metalling. Assuming this for the ordinary irregularity over which the loaded wheel has to pass, then according to the laws of descent of falling bodies the effect of the loaded wheel descending from that height, will be to its effect descending from any other height directly as the square roots of the respective heights. The necessity of using small stone and of a smooth surface is therefore evident, and a reference to the table in the foregoing Chapter, showing the weights which crush different qualities of stone, will assist in determining the description of metalling suited to each particular traffic.

The elasticity of stone is of great importance because it is of all properties that which contributes most to preserve the durability of metalling under the shocks it has to sustain. These shocks are caused by the impulsive force with which a loaded wheel rolling over a prominent stone strikes in its descent the surface beneath it. The capacity with which different sorts of stone are endowed to resist such impulsive force is found to increase with the square roots of their elasticity. To this property we are to ascribe what is commonly observed, that roads made over elastic soils, for instance bogs, are found to wear less than those made upon more unyielding foundations; and from some observations made in the neighbourhood of Bridgewater it appears that the quantity of materials worn off a piece of road made over a *rock*, compared with the quantity worn off an equal extent of road made over the "*naked surface of the soil*" is in the ratio of seven to five. In this manner by a comparison of the wear on a road over a well drained *bog*, with that of a road on a *rock* or other foundation the advantage which an elastic surface affords in the way of diminishing or preventing the comparatively rapid wear on a less elastic surface can be easily estimated.

COST OF MATERIALS.

The cost of broken stone materials will consist chiefly of three items, viz.:—Quarrying, Breaking, and Carriage. Quarrying for road materials is generally executed by laborers provided with crow-bars and picks, the inconvenience and difficulty of providing powder in many localities being such that blasting is but rarely resorted to, In quarries where the stratafication of the stone is open laborers with crow-bars, sledges, wedges and picks may be employed with convenience and economy; and without more than common skill and expertness one labourer will turn out from 5 to 8 tons a day.

If a quarry should be composed of compact close jointed stone, the operations of the quarrymen will be quite unproductive unless assisted by occasional blasting to detach large blocks and shake or loosen compact masses. The stone may then be removed by laborers with comparative ease. The removal of stone by blasting alone is very expensive and a person will rarely find his advantage in employing it unless for the purpose of loosening masses of stone which can afterwards be removed by manual labor. In some quarries however, a few blasts laid with judgment will bring down several hundred tons of stone, when other means would be tedious, expensive, perhaps unavailing. In a quarry with a high breast and the stratafication of the stone upright or but slightly inclined from the perpendicular, one or two blasts at the foot or lower part, will do much execution. This is at once obvious. With the stratafication vertical, as is supposed, or but little inclined from the perpendicular, the superincumbent mass having no support but the bottom part in which the powder is placed, when this is blown out the whole breast of the quarry from top to bottom must come down.

This mode of blasting rock, where the stratafication was favorable, has been practised with equal success and economy in the execution of several roads in Ireland under the directions of that deservedly distinguished engineer officer, General Sir John Burgoyne, to whom the merit of the plan is entirely due.

The circumstances attending the operation of blasting are so many and various that we must be prepared for a diversity of result even when the experiments made are apparently the same; and hence practically speaking, to assign the precise quantity of powder required for blasting a given quantity of rock becomes a problem of rather difficult solution. It may be stated as the result of experiment in ordinary cases that 2 oz. of powder will blast one cubic yard of rock.

The mode of preparing a blast is as follows. A cylindrical hole or chamber is bored into the rock with a *drill,* in the lower part of which chamber the powder is placed: a "*needle*" or fine rod of copper is then introduced, the lower end bearing upon the powder; the hole is then filled around this needle with dried clay firmly compressed with the *tamping* irons: the clay being duly consolidated the needle is withdrawn and a quill or straw filled with powder put in its place. An ignitible communication is thus formed between the charge of powder in the bottom of the hole and the exterior part of the rock to be blown up. From the outer part of the quill or straw a train of powder is laid of sufficient length to allow the men in the vicinity to move off to a safe distance before the fire applied to the extreme end of the train has time to communicate with the body of powder in the bottom of the chamber. This was the old mode of forming a connection between the charge of powder and the exterior of the rock to be blasted; it is now almost entirely superseded by the patent "*Safety Fuze,*" which combines the threefold advantage of greater safety, certainty, and economy. A charge seldom or never misses with the *safety fuze,* though frequently with the old plan. The consequence has been the occurrence of numerous and appalling accidents. The first charge having missed, when it would be attempted to recharge a sudden explosion might take place, it often has taken place, in the very act of clearing out the chamber for a fresh charge. Where the use of the patent *safety fuze* is general such accidents are of very rare occurrence, and hence for persons having charge of public works to compel were it necessary, the adoption of the *safety fuze,* could be regarded in no other light than as a humane precaution having for its object the preservation of human life, such compulsion would be a mercy.

The *safety fuze* is a flexible tube of tarred canvass about three-eights of an inch diameter, and filled with fine powder, upon being ignited it burns with regularity and certainty even if immersed in water, at the rate of about two feet per minute. It is sold by most powder merchants in "*Coils*" each of 24 feet at ten pence per "*Coil.*"

Good blasting powder may be had for *Fifty Shillings* per barrel of 100 lbs.; and when the rock to be blasted is not close grained or is intersected by open fissures, a mixture of *one-fourth* of dry saw-dust with the powder will save considerable expense and will in the circumstances answer the purpose of blasting just as well as powder alone.

The chamber hole for a blast should be sunk in a direction slanting or oblique to the face of the rock, so that the direct line or shortest distance from the bottom of the chamber to the face of the rock shall be less than the length of the hole drilled through the rock for introducing the powder. This direct line is called the "*line of least resistance*" and with a properly prepared blast the rock will first yield in this direction. If the chamber or hole was bored along the "*line of least resistance*" the powder when exploded, would drive the tamping through the hole and leave the rock unshaken. Whence the obvious necessity in driving holes for blasting of taking care to give them a direction oblique, but never perpendicular to the face of the rock.

Extensive experiments have been made by Valiere, Etienne, Belidor, Mouze, and Le Febre on the explosive power of different charges of powder to spring mines in ordinary soils, which experiments, as being similar in their nature to the operation of blasting rocks afford us some useful and practical information on the subject. From the results of these experiments we gather that the charge bears nearly a direct proportion to the solid contents of the excavation made by each explosion, or, which comes to the same thing, the weight of powder in each charge should be proportional to the cube of the line of least resistance. Müller states that when the diameter of the excavation is equal to twice the line of least resistance, the understated charges are requisite;

		lbs.	oz.
3	feet for the line of least resistance require	2	8
4		6	0
5		11	10
6		20	4
7		32	2
8		48	0
9		68	3
10		93	12

The above quantities of Powder are very nearly proportional to the cubes of the lines of least resistance; but as the experiments were confined to springing mines, the charges would be found much too great for our usual blasting operations.

The following Table will be found to accord better with ordinary practice* in blasting:—

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* Taken from the Instructions for Blasting Rock by the Shannon Commissioners.

Lines of least resistance. Ft.	In.	Charges of Powder. lbs.	oz.	Lines of least resistance. Ft.	In	Charges of Powder. lbs.	oz.
1	0	0	0½	4	9	3	5½
1	3	0	1	5	0	3	14½
1	6	0	1¾	5	3	4	8¼
1	9	0	2½	5	6	5	3¼
2	0	0	4	5	9	5	15
2	3	0	5½	6	0	6	12
2	6	0	7¾	6	3	7	10
2	9	0	10¼	6	6	8	9¼
3	0	0	13½	6	9	9	9¾
3	3	1	1	7	0	10	11½
3	6	1	5½	7	3	11	14½
3	9	1	10¼	7	6	13	3
4	0	2	0	7	9	14	8¾
4	3	2	6½	8	0	16	0
4	6	2	13½				

These proportions will answer for most cases but for the sake of greater accuracy a few experiments could be made in the commencement of any work, and a table drawn up setting forth the result of such experiments. In blasting upon a large scale, advantage may be taken of fissures in the rock and other circumstances by which the charges may be considerably reduced.

As it is useful at times to know the space in round holes that given quantities of gunpowder may occupy, the following table will serve to make the calculation.

Diameter of the hole.	Powder contained in one Inch of Hole.		Powder contained in one Foot of Hole.		Depth of Hole to contain one lb. of powder.
Inches.	lbs.	oz.	lbs.	oz.	Inches.
1	0	0.419	0	5.028	38.197
1½	0	0.942	0	11.304	16.976
2	0	1.676	1	4.112	9.549
2½	0	2.618	1	15.416	6.112
3	0	3.770	2	13.240	4.244

One pound of powder loosely poured in, but not close shaken, will occupy about 30 cubic inches;—a cubic foot weighs about 37½ lbs.—(Instr. Shannon Works.)

The next subject for consideration is the cost of Breaking Stones, and this, it is manifest, must vary with their hardness and the rate of laborers wages. Machinery is not employed to break stone for road metalling, but there can be no doubt that in the vicinity of towns where large quantities are required, steam and water-power might be applied to such use with greater economy than manual labor. We have had experiments made at the Berehaven Copper Mines with the view of ascertaining how far machinery could be economically employed in breaking stones. The stone experimented upon was all hard quartz, more difficult to be broken than almost any other description of stone, and yet the result proves that this hard stone can be broken by machinery to any requisite size and at less cost by a great deal than soft stone by manual labor.

The following particulars of the experiment may be useful.

A condensing steam engine of 37 horse power consuming 2 cwt. of coals per hour was employed to drive two pair of *case hardened* cast iron rollers, each pair of rollers being adjusted and placed in a horizontal position so that the stones when passing between them should be crushed to the required size; each roller was 2½ feet long and 18 inches diameter weighing 14 cwt. and revolving on strong wrought iron axles 7 inches diameter, all strongly framed together. The lumps of quartz were thrown down upon the rollers, having been previously reduced to such size as to pass through a ring from 4 to 5 inches diameter. By the revolution of each pair of rollers the stones thrown upon them were made to pass between them, and so were broken into small pieces corresponding in size with the space between the rollers. The Engine and Rollers broke 9 tons 3 cwt. per hour to such size as to pass through a ring *one-half* inch diameter. The rollers were fed by three girls and the stones when broken removed by four men and four boys, each traversing in the move to and fro with the broken and unbroken stone an average distance of 25 yards. The total cost of Engine power was 3½d. per ton, and the expense of rollers, carriage, removal of stone, &c. was 5d. per ton, making on the whole 8½d. *per ton* for breaking *hard quartz* a size sufficient to pass through a *half-inch* ring.

The expense of breaking the quartz stone by the same process of a size to pass through a ring 1½ inch diameter was *one-fourth* of the former, that is about one half-penny for engine power and three half-pence for other expenses, making 2d. *per ton.* One pair of rollers will stand for forty days breaking hard quartz for seven hours a day, after which their surfaces becoming very much worn and indented will render them unfit for further use.

The chief objection to breaking stones between rollers is, that good part of the stone will be crushed smaller than might be desired. When the foregoing experiments were making it was suggested to employ *grooved* rollers in order to meet this objection.*

In breaking stone by manual labor, short handled light hammers are better than heavy hammers or those with long handles. Each handle should be of ash 20 inches long and the hammer 1½ ℔. weight, with two well steeled rounded faces. A hard stone should be used as an anvil upon which to break the stone.

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* We are indebted to Captain Reid of Berehaven for superintending the experiments on the application of steam power to the purpose of stone breaking. In his valued communication he remarks—"I think a steam engine of eight horse power working one pair of *grooved* rollers 2 feet long and 16 inches diameter will crush stone to pass through a ring 1¼ inch diameter as fast as men can well bring stones and remove them from the rollers after being crushed."

An expert labourer will break in a day 2½ tons of limestone of a size to pass through an inch and half ring, and of hard siliceous stone 1½ tons in the same time. The degree of hardness of the same quality of stone is often so different and so much does the quality of work which a labourer can put out of hands depend upon it that sometimes he will not average half that quantity in a day; but still in ordinary cases the foregoing will be found the usual return of a good stone breaker.

Broken limestone for road repairs can be procured at the quarries in the vicinity of Cork for the following charges per ton—

Quarrying	5d.
Breaking of a size to pass through a ring 1¼ inch diameter	5d.
Breaking of a size to pass through a ring 1½ inch diameter	4d.
Carriage	6d. per ton per mile.

Stones for repairs should never be larger than may pass freely through a ring 1½ inch diameter Angular stones will always knit together better and sooner than rounded pieces; and hence gravel is not well suited for road repairs, for unless it be well separated from its usual mixture of sand or earth and the rounded lumps broken down into angular pieces, it will never unite into a compact mass.

Hard river gravel when convenient to a road is not to be lightly rejected as material, the use of it will be such a saving, unless indeed the road be one upon which very great intercourse exists; and even upon such it may be employed if the lumps be large enough to admit of being broken.

Let the situation be ever so convenient, Pit-gravel can seldom be used with economy for roads of much intercourse. It is next to impossible to separate it from the earth generally mixed with it unless at an expenditure of labor more than sufficient to procure good broken stones.

We have had experiments made with a view of determining the increased bulk of solid stone when broken to pass through rings of three different sizes; the particulars of these experiments, which may have their use, we here subjoin—

100 Cubic feet of solid stone when broken to pass through a ring 1½ inch diameter measured 205 cubic feet.
2 inches do. do. 190 do.
2½ inches do. do. 170 do.

From the above it is obvious that the cavities occupy a very large proportion of a bulk of broken stone and this circumstance warrants us to infer the advantages of broken stone as a mode of drainage, the interstices between the stones rendering the process of filtration perfectly efficacious.

It also follows from this experiment that solid stone, of which 14 cubic feet usually weigh a ton,* will when broken weigh as under.

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* The weight of stones does not usually differ very much: in general, it will not vary much from the above statement. Bulk can easily be proportioned in all cases according to

Size of ring through which the broken stone will pass.	Weight of broken stone per cubic yard.	
Inches.	Cwts.	lbs.
1½	19	2
2	20	59
2½	22	39

When it becomes necessary to carry materials from a remote distance the gross expense is thereby considerably increased. In proof of this we need only refer to the foregoing data which make it quite manifest that the cost of carriage for one mile only exceeds the expense either of quarrying or breaking; and hence it is that we ought carefully examine whether suitable materials may not be had near us before we go to a distance to look for them.

In order to diminish as much as possible the carriage of materials and to provide a good supply when wanted it will be convenient to form *depôts* along the Road to hold broken

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the specific gravity deducible from the table which we have given in the latter part of the preceding chapter.

stones. These depôts should be placed at such intervals as to render ordinary repairs practicable by manual labor only: an interval say of from one to two hundred yards would suffice, as in that case a man with a wheel-barrow could easily supply the intervening parts of the road with the quantity of material required for their repair.

Apart from this consideration, depôts would furthermore be of advantage, inasmuch as it is a direct saving of money to have a quantity of stone broken in the fine season, the proper one for such work, and collected together ready for use rather than wait for inclement weather when the work could be done not so well nor at all so cheaply.

Depôts present this further advantage that they serve as receptacles for stone broken or unbroken, that would otherwise have to be filled up on the road-side—a thing attended with great inconvenience, with danger to passengers and injury to the road, to which we may add that it narrows the travellable part of the road to a very small width thus augmenting the danger of a collision between vehicles coming from opposite directions as well as with the heaps of stone so awkwardly placed in the way. Such heaps of stone present also no small obstruction to effectual cleansing and surface drainage.

The effect produced on the surface of roads by wheels with different breadths of *tier* is a subject which has engaged a large share of public attention generally as well as of several committees of both Houses of Parliament. Experience and observation, the surest, the only guides, to practical knowledge, have led those engaged in the repair and others concerned in the use of roads to conclude, that it must be a matter of importance so to adjust the proportion between the wheel-tiers and the load to be carried that the wheels may not sink into the surface.

Narrow tiered low wheels when heavily laden cut deeply into the road crust, not only destroying the surface but creating much additional draught.*

Wheels with wide tiers are on the contrary less injurious because of the greater area which they present, and which will be found to sink less into the road crust under the same load.

The Legislature has deemed this subject of sufficient importance to prohibit the use of wheels with narrow tiers except under severe, almost prohibitory taxation. A light tax has on the contrary been laid upon wide tiers, but experience shews that the distinction so made dont appear to be judiciously exercised.†

Those acquainted with the employment of wide tiers must be aware of the ingenious shifts and contrivances resorted to for the purpose of evading the use of wide wheels. Wheels with fellies twelve inches wide have been made to bear on but two inches of tier by the peculiar mode of shoeing or binding.

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* The amount of resistance to draught, from even the partial sinking of wheels through a road surface is greater than what is generally supposed. The laws by which this resistance is governed will be found fully investigated in the subsequent Chapter on Draught.

† This law is chiefly confined to the English Turnpike roads.

Now as we are aware that the sinking of narrow tiers through a road crust must create resistance to some extent, it cannot be supposed that carriers would evade the use of wide wheels did they diminish this resistance so far as is supposed. At any rate facts plainly shew one thing that the legislative enactments in this respect are more evaded than observed; whence we cannot well resist the conclusion that the enactments of the legislature have out-stepped the just limits which experience and the necessity of the case would prescribe in applying a remedy to the injury caused by wheels with narrow tiers.

It has been observed, and with some truth, that legislation on such subjects is often unnecessary, sometimes injurious. As it is the direct interest of those in the way of using roads to have them in good condition, it is no more than reasonable to suppose that from a regard to their own immediate interest, if from no other motive, they would avoid the use of wheels of a sort calculated to do much injury to roads.

It would decidedly be for their interest to use such wheels as by sinking least through the surface would diminish the draught as much as possible.

Much difficulty is felt in fixing a standard breadth for wheels proportioned to the loads they have to carry, because in proportion to the hardness of roads will it be necessary to vary the width of wheels; and as the degrees of hardness are almost beyond number, the breadth of tiers of wheels must also be proportionally uncertain and difficult of determination.

The durability or coherency of a road crust under different breadths of tiers, is so intimately related to the friction, or resistance to draught with those breadths, that there is good ground to believe experience could better adjust the proportion of the one to the other than any legislation, even the most enlightened and guarded in its provisions. Occasionally matters will arise which demand the interference of the legislature; yet on the whole practical experience appears to be the best guide and would, most likely better serve all interests concerned than any legislation, though it had proceeded on the safest principles.

It may be observed generally that a width of tier causing least resistance to draught should be preferred. That width will not be found to injure a road crust seriously and generally speaking, no width of tier should be prohibited unless it be so narrow as quickly to crush the stone to powder or work the road into ruts.

Upon the whole we may lay it down that a wheel with four inches breadth of tier can be loaded with 15 cwt. without injuring a road crust made with ordinarily hard stone; and wheels of that width will not be found to sink through it nor create more friction than is fairly allowable to an ordinary common road.

Another cause of expense in repairing roads arises from the shape of the wheels used upon them. The injurious effect of wheels with conical tiers have been so often proved before Committees of both Houses of Parliament, and so clearly demonstrated in almost every treatise on wheel carriages that any observation upon them here would be needless were it not that they are yet so extensively used in England. In Ireland and Scotland coned wheels are now rarely seen those of a cylindrical form being generally substituted. Now that so many proofs have been given of the diminished draughts with cylindrical wheels and of their less injurious action on roads, and when moreover we see decided preference given to this wheel by every person of judgment, it is matter of no small surprize yet to find the coned wheel and bent axle in extensive use.

FOOTPATHS.

CHAPTER VII.

FOOTPATHS should be made on all roads of much intercourse, because the intercourse itself and the consequent liability to derangement would of necessity interfere with the comfort of pedestrians, an object to be provided for equally with a good carriage way for beasts of burden.

The surface of footways should never be under the level of the middle of the contiguous roadway; it should also have a sufficient fall about 1 inch to each yard to discharge surface water towards the road and should not in general be less than five feet wide. The width and finish of the surface must however always vary with the necessities of the probable intercourse. In localities remote from cities and towns the above is a sufficient width but eight or ten feet will be necessary for the approach-roads of populous towns.

The streets of cities and towns should however be provided with two footways—one on each side—as spacious as possible, say fourteen to fifteen feet each. The narrowness of streets will not always admit of a strict adherence to these dimensions, as it would in that case be necessary to encroach upon the carriage-way.

In short the breadths of Footways and carriageways in towns must be variable according to circumstances: sometimes it may be necessary to reduce them to even a lesser width than would be chosen for roads without any thing like the same amount of intercourse, as being remote from cities and other populous localities.

The description of covering adapted to footways varies with their situation. The best covering for those remote from towns is small broken stone or screened gravel, which should not be larger than a *half-inch* cube. Footways near towns should have their surfaces paved with oblong pebbles about the size of a goose egg. Those in cities and towns are usually flagged, but a covering of *Asphalt* having been of late brought into extensive use upon the principal footways in Paris and London has proved not only a very durable material but also a much more agreeable footway, invariably preserving a certain degree of roughness whilst flagging on the contrary assumes an unpleasant degree of smoothness.

The mode of making gravel and paved surfaces for roads as already described differs but little from the method to be adopted in making footways with these same materials. Indeed the only difference consists in using gravel and pebbles of smaller size on footways than carriage ways, and making the covering crust of the former but four inches thick, which will be sufficient if the material with which the pathway is raised be properly consolidated.

When footways are to be flagged, the ground under them is to be carefully prepared, as the failure of flagging is always owing more to insufficient bearing than to any defect in the flags themselves. The ground is to be brought to a uniform surface, and then well rammed or beaten with a heavy maul so as to afford a firm and uniform bearing for the flags. The filling stuff should be composed of quarry rubbish and stone chips well consolidated and then laid over with a coat of well prepared lime mortar from 1½ to 2 inches thick on which the flags are to be firmly bedded. Care must be taken to have the joints set square and the upper surface flush or free from projections at the joints. It is a common practice with tradesmen anxious to show good even surfaces over the meeting joints of flags, to drive *stones* under their *low* edges and so to lift them to the level of those adjoining. But, as it invariably happens, the flags so lifted lose the uniform support which the entire surface requires and which can be had only by laying them flush on uniform bearings. When flags are supported on their outer edges only, the points of support soon sink into the ground and the flags immediately lose their proper level; or if the points of support do not yield, the flags being seldom more than 2 inches thick, are soon broken into fragments for want of sufficient bearing. The practice of pinning under flag joints is therefore to be avoided as much as possible.

The edges of the flagging should be trimmed and cut to range fair with the course of the carriage way, and a deep curb stone from eight to ten inches thick should be set along the edge of the flags flush with their upper surface and sunk in ground about 10 inches, or at least as much as they stand or measure above it. Outside these curbs water-tables should be paved for a breadth of three feet.

The flagging best suited for footways is that having a roughish surface. When flagging is of a compact fine texture the effect of even partial use is to convert it into a polished surface; and we need scarcely remark that an extreme degree of smoothness is any thing but desirable on a footway.

The cost of flags must vary according to the locality and the facilities of procuring them. In most seaport towns good flags may be had for 2s. 8d. to 3s. 0d. per square yard: flags of inferior quality may be had for from 2s. to 2s. 4d. the yard. The cost of laying will vary with the wages of workmen, but a good working mason and two laborers will lay two square yards in an hour.

The public Footpaths of London and Paris have been latterly laid to a large extent with *Asphalt,* which when properly prepared and applied makes a very durable, clean, and pleasant surface under foot. Asphalt, though but lately substituted for flagging on public footways, was well known to the ancients and greatly prized by them for its cementing properties.

It is a kind of bituminous stone, supposed to have been the principal material used in cementing the walls of the temple of Jerusalem and of Babylon.

Melted and mixed with other ingredients it forms an excellent cement, impenetrable to water, possessing a considerable degree of elasticity, very tenacious and always in a small degree rough. These qualities, not to mention its freedom from mud, render Asphalt at once a pleasant and a safe footing far superior to the best description of stone-flagging. Mines of Asphalt are worked near Neufchâtel, at Pyrimont Seyssel on the eastern side of the Jura Mountains and in many other places; but the most approved is that procured from the latter place, for the preparation of which a company is formed having two principal depôts, at Marseilles and London. We have had a practical proof of the excellence of this material prepared under "Claridge's patent" in the specimens laid down in Westminster opposite the Horse Guards so far back as the April of 1838. With a thickness of only half an inch it has withstood the traffic of that great thoroughfare up to the present time without any apparent change except a greater smoothness of surface.

The secretary of the company established for the sale of Seyssel Asphalt gives the following description of it.

"This Asphalt is a Bituminous Limestone obtained from an inexhaustable Mine at Pyrimont in the Jura Mountains. Previously to its introduction into this country in 1838, the material had been used for many years in France and from its great utility was extensively patronized by the government of that country.

Among the various uses to which it can be applied the following may be enumerated. For Foot-Pavements, public and other; in the carriage approach to mansions, garden walks, and terraces, roofing, covering of railroads, &c."

In cities and populous towns there should be *crossings* for footways laid across the carriage way at the junction of the streets. These crossings should be made of timber or hewn stone. If the latter material it should be of hard quality nine inches deep and of five feet wide; the surface grooved across the line of draught to prevent horses from slipping. The upper surface of the crossings should be elevated, say about two inches, above the general level of the roadway and should have a pavement at each side four feet wide sloping regularly from the surface of the crossings to the contiguous surface of the street so as to prevent any unpleasant jolt to a carriage when driven over. If crossings be made of timber, they must have long scantlings dowelled together five inches thick, grooved on the upper surface and paved on each side alike with those made with stone.

INSTRUMENTS, TOOLS, &c.

CHAPTER VIII.

A VATIETY of Instruments, Tools, &c., are used in making and repairing roads; and those employed in making differ widely from such as are used in repairing them. It is not to be expected that a work professedly designed for practical men should enter into the *minutiæ* of details that properly fall within the province of the Engineer; and hence the reader is not to look for more in the present chapter than may be necessary to illustrate the practical use of such Instruments, &c., in ordinary road work.

The instruments and tools in ordinary use for road work are *Theodolites, Spirit Levels, Sex-*

tants, Plummet Levels, Cubic Measures for broken stone, Rings, Screens, Drainage and Skinning spades, Bog knives, Hammers, Anvils, Rakes, Shovels, Wheel-barrows, Picks, Scrapers, Rollers, Scraping Machines, Quarry Tools, &c., &c.

It has been already mentioned that a six inch *Theodolite* will be sufficient for the ordinary practice of road work: indeed if used with care it would even answer the purposes of railway works.

The *Spirit Level* is a smaller and more portable instrument yet not so convenient nor so generally used for road work as the Theodolite, though in experienced hands it can be applied equally with the Theodolite upon almost every description of road work.

The *Sextant* is not generally used for road making, though so portable that it may be carried in the pocket: it is extremely accurate, but more used in surveying operations than in road work. As respects the filling up the details of road surveys no instrument is better suited or more strongly recommended.

The methods of using the foregoing instruments are fully and very well described in Simms's Treatise on Mathematical Instruments.

The assistance of the Theodolite and Spirit Level is quite indispensable in tracing the proper course for new roads and making accurate surveys and sections of the ground over which they are to pass. Without the aid of detailed maps and sections, shewing the principal objects along or adjacent to proposed roads together with the features and undulations of the ground, the heights of floods caused by the overflowing of rivers and the like, the engineer cannot ascertain the best course for a line of road nor determine the longitudinal inclinations to which it should be brought. It was the practice of former times to make roads in straight lines following the undulations of the surface as far as the eye could see; and no doubt instruments of any sort were then of no use; but now that easy longitudiual inclinations are accounted of paramount importance, we are obliged to depart from those direct courses, and the use of instruments becomes indispensably necessary to obtain easy curves, and gentle gradients or inclinations. Same time the use of instruments assists us to avoid the construction of high embankments or deep excavations which are objectionable on more grounds than the heavy expense their first formation always entails.

The *Plummet Level* is useful for forming the surface of roads with a uniform cross section. It consists of a long piece of wood, to the middle of which a broader piece is fitted at right angles with a plummet suspended, the broader piece being kept in its rectangular position by two side stays. Fig. 9 represents one of these levels and if the horizontal bar be made eight feet four inches long, or 100 inches, and provided with four moveable gauges working up and down in dove-tailed grooves, it will be found easier of application than of larger size levels with more gauges. In addition to its use in forming the cross figure of a road, it might also be applied in forming short planes of inclination between detached points the levels of which had been fixed with a Theodolite or Spirit Level. For this purpose one gauge only, that at the extreme end, is to be used.

The Plummet Level may be made to show all planes of inclination between 1 in 10 and 1 in 1000 and with sufficient accuracy for ordinary purposes; particularly in reducing acclivities on old roads, and even in putting in planes of inclination on new roads, if they be not more than from one to two hundred yards in length. When they are longer the Theodolite or Spirit Level only can be relied on.

If the lower bar of the plummet level be made 100 inches long and the moveable end gauge 10 inches long divided into inches and tenths, the gauge will be a decimal division as well as an aliquot part of the base. One inch on the vertical end piece or gauge will be the hundredth part of the base; and a tenth of an inch, which is the smallest division on the vertical gauge, will be the thousandth part of the base.

The following table shews the rate of inclination corresponding with different depressions of the end gauge below the bottom edge of the plummet level, the suspended plummet being supposed to hang truly perpendicular to the horizontal bar at bottom and over the middle of it.

Depression of End Gauge.	Rate of Inclination.	Depression of End Gauge.	Rate of Inclination.
Inches.		Inches.	
0.1	1 in 1000	2	1 in 50
0.2	1 in 500	3	1 in 33⅓
0.3	1 in 333⅓	4	1 in 25
0.4	1 in 250	5	1 in 20
0.5	1 in 200	6	1 in 16⅔
0.6	1 in 166⅔	7	1 in 14 2/7
0.7	1 in 144 2/7	8	1 in 12½
0.8	1 in 125	9	1 in 11⅑
0.9	1 in 111⅑	10	1 in 10
1.0	1 in 100		

Cubic Measures for broken stones are usually made of timber in the form of a square trough, the four sides being each three feet long and eighteen inches deep without top or bottom. It is provided on each side with two iron rings for timber handles to pass through, whereby, when filled, it can be lifted up with ease, leaving the stones on the ground in heaps each half a cube yard in dimension.

Rings are used for testing the size of broken stones, being preferred as a measure to scales and weights on account of their greater simplicity. The rings to be provided with handles and the stones to be of a proper size should pass freely through them.

Screens are useful to separate gravel from the earthy particles and sand with which it is generally combined. Screens are made with a frame of timber and small rods of iron spaced about three quarters of an inch asunder, the material passing between the rods being rejected as too small and the larger particles alone being reserved as fit for road repairs, and any above an inch in size being laid aside to be broken.

Drainage and *Skinning Spades* are made purposely for their respective work and require to be fashioned accordingly in a peculiar manner. Drainage spades are narrow, having a width of six inches, often of only three, according to the stiffness of the soil through which the drains are to be sunk. Skinning spades are intended for removing the grass sod which is found to grow rapidly on the sides of roads not much travelled over by carriages, and unlike drainage spades, should have wide flat edges with short handles. Each is shewn by figs. 10, 10′, the first representing the draining spade and the second the skinning spade.

Bog Knives greatly facilitate the formation of drains through bog soils. They are formed of iron with wide blades having two edges and a short timber handle passing at right angles through an eye on the top of the knife. A man accustomed to the use of the bog knife will cut both sides of the track of a drain through bog with great rapidity, after which the material between these cuts can be easily removed by ordinary laborers. See fig. 11.

Hammers are made of different weights according to the size to which they are intended to break stones. Hammers of six pounds weight will reduce blocks of quarried stone to a proper size for the stone breaker. The stone breaker's hammer ought to be about one and a half pounds weight; and both should be well steeled and brought to a small rounded face. The small hammer should not be above half an inch diameter on the face and of the shape shewn on Fig. 12, the handles about twenty inches long.

Anvils are of great use in facilitating the operation of stone breaking, and should be of stone the hardest and most compact that can be procured. The stone to be broken is placed upon the anvil, and if struck smartly will be immediately broken; but if it be attempted to break stones in a heap, without placing them on the anvil, they will fly from under the hammer and by that means much of a man's labor will be lost.

Rakes are absolutely necessary to keep a road from wearing into ruts, particularly after the application of fresh metalling. Immediately an impression is made in the surface of a road, it should be levelled in by raking; in this way the surface will be brought to a compact and uniform state by a very little attention. Rakes are made with timber heads ten to twelve inches wide, set with strong iron spikes two to three inches long, having slender ash handles about six feet in length, see Fig. 13.

Shovels for spreading stones are composed of a number of prongs or forks. Pronged shovels enter heaps of broken stones more easily than those made in the ordinary way, and prevent the admixture of earth or sand with stones. Fig. 14 represents a shovel of this construction.

Wheel-barrows are useful for road repairs: they should have cast-iron wheels and ash frames and handles bolted together with wrought iron

The sides and ends should also be well splayed and the box not above nine inches deep, see Fig. 15. It will be convenient to fit hooks on the sides to hold one shovel and one pickaxe or rake.

Picks are made of iron with bent arms having a large eye in the centre into which a wooden handle is fitted about twenty six inches long. The iron arms are pointed with steel on the extremities, and should not weigh over eight pounds. They are frequently made to weigh fifteen pounds; but in general that is too much for convenient use. They frequently have a chisel point on the extremity and a fine point on the other: a figure very well adapted to ordinary road work, particularly when the pick is used along with the rake for road repairs. See Fig. 16.

Rollers properly constructed are of use for consolidating the crust of a newly formed road. They should be made cylindrical in form, of cast iron from three to four inches thick and five feet wide, which will weigh from three to four tons. No weight should be placed on the axis beyond that of the shafts to which the horses are yoked. Such roller being passed over a newly made road surface half a dozen times will so compress and consolidate the materials that wheel carriages may roll over them freely enough.

Scraping Machines have been contrived for removing mud and dust and have been found to economise manual labor to no small extent. Some are contrived to move on low wheels carrying a number of small iron scrapers. The machine is so constructed that when it operates on the road surface the weight of the framing is thrown on the projecting scrapers by lifting the body upwards so as to clear the road of the wheels, then by drawing the entire backwards the mud or dust is pushed before the scrapers. A machine has also been contrived which by the revolution of a large barrel· or cylinder set all round with brooms or scrapers and fixed on the axle of ordinary waggon wheels, not only cleans the surface but also takes up all mud or dust, and this serves the double purpose of a scraping machine and of a carriage for conveying away the stuff scraped off the surface. The use of this latter machine is confined to cities and towns where it has been found of great use.*

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* From calculations made by the municipal authorities at Manchester, on the relative advantages of machinery and manual labour, in cleansing the streets, the results of which are given in a table, it is shown that the extent of surface swept is the same, although not the extent of streets, arising from the more or less frequency of sweeping over the same surface; so that by cleansing the streets with Whitworth's street-sweeping machine, three times a week, the quantity of mud produced on the surface is five times less, than when they were swept by hand, twice in three weeks, and thirteen times less than when swept but once a week.

		Number of Yards swept.	Number of Loads removed.	Average Number of Yards swept to produce a Load.
District swept by machine three times per week.. ..		5,500,000	1,285	4,338
By manual labour:				
Twice in three weeks township, ...	1841-2	5,500,000	6,400	859
Once a-week „	1838-9	5,500,000	17,000	343

The losses caused by the dust and dirt in the streets are stated to be very great; Mr. Mivart, of Mivart's Hotel, estimates his actual loss at about £865 per annum, whilst shop-keepers in Oxford-street, and Regent-street, state that they lose annually from £30 to £300 per annum, by the destruction of their goods by the dust, &c.—*Papers on state of the Streets of the Metropolis.*

Quarry-tools having been treated of in a preceding chapter, it is needless to do more than refer to the figures on the annexed plate representing them.

Fig. 17, represents a Sledge Hammer or Mallet.
18, — Borer or Chisel.
19, — Wedges.
20, — Scraper.
21, — Claying Bar.
22, — Needle.
23, — Tamping Bar.
24, — Fusee.
25, — Crow Bar.

The above tools are used in boring holes for blasting rock with powder, the operation being conducted in the following manner. The borer or chisel is held by one man and is struck with a sledge hammer by another, the man holding the chisel turning it at every blow so as to cross the previous cut. The boring operation is occasionally suspended until the hole is cleared with the scraper, after which the boring is again resumed 'till the hole is of the required depth.

If water should penetrate the sides of the hole, some tough dry clay is introduced and the Claying-bar driven in with force. By this means the clay is forced into all the crevises, absorbs the moisture and staunches the rents through which more water might enter. When the safety fuze is used the Needle may be dispensed with; but in either case the Tamping Bar is employed in ramming round some compact dry clay.

The Crow-bar is used in loose open quarries to detach blocks of stone where blasting is unnecessary.

DRAUGHT UPON ROADS.

CHAPTER IX.

THE determination of Draught upon Roads necessarily involves the consideration of three distinct Agents, namely, the vehicle employed, the road upon which it moves, and the power which effects locomotion. Each of these affords a subject of inquiry independent of the other. We shall therefore investigate them successively and having done so, we shall then inquire into the Draught dependent on their combination.

The vehicle used upon roads for conveying heavy loads are the two wheeled car and the four wheeled waggon. There exists much difference of opinion as to the relative advantages of these machines.

It is asserted that the two wheeled car can be made of a proportionally lighter draught than the four wheeled waggon, that the traces can be more successfully inclined to suit the most favourable angle of pull, that it can be made more available for ordinary variable loads, that its wheels can be made on the whole of greater size than those of the four wheeled waggon, that it can go round sharper curves, and that a horse working alone is capable of performing more work than when forming one of a team and that consequently there results a saving of nearly 3 to 2 from this increased effect.

On the contrary, it is maintained that although the fore wheels of the waggon are made smaller than the hind ones or than is necessary yet in descending declivities the waggon will not throw any portion of its weight upon the horse's back, that in a car each horse must be of superior quality and therefore more expensive than those of a team where the average power only is considered, that the wear and tear, first cost, and expense of several small carts is greater than that of a single waggon carrying the same load and that in consequence if we compare the relative advantages of the waggon and the car in the way of economy, they will be found in favor of the waggon in the rate of 4 to 3.

Although a number of facts and long experience give us reason to suppose that good horses have done more work on inferior roads with cars than with waggons, that these cars are more easily loaded and unloaded, do less injury to the roads, and do not require more horses in action than are sufficient for the work to be performed; yet we are strongly of opinion that with better roads the four wheeled waggon would have the advantage under all the circumstances of variable inclinations and heavy loads.

The power required to move a car upon a level road depends upon the friction of the

Axles and the resistance to rolling. The friction of the axles is the same in nearly all cases as long as the load and car are the same; but the resistance to rolling, having its immediate action at the tire, must be variable according to the description of road upon which the wheels move.

The friction between the surfaces of the *axle and its box* may be considered equal to one-eighteenth of the pressure, when they are well made and oiled. In ordinary cases however it is much more. We shall suppose it $\frac{1}{12}$th in the present instance.

Let d represent the diameter of the axle and $2r$ that of the wheel. Now suppose the wheel to be supported on its axle and a power applied at the tire which is just sufficient to make it revolve it is evident this power will equal the friction at the axle decreased in the ratio of $2r : d$, and may be represented by the simple expression.

$$\text{Power} = \frac{\text{Weight}}{12} \times \frac{d}{2r}$$

In this case the ratio of the velocity of the power to that of the resistance is as $2r : d$. Again when the vehicle with its load is drawn along a road it will be under similar circumstances as the wheel just now mentioned as far as regards the power necessary to overcome the friction of the axle, for the relation between the velocities of the power and resistance is the same. The only thing which prevents the two cases from being identical is the difference in the amount of the weights upon the axle;—in the former case, it was the weight of the wheel alone in the latter it is the weight of the body of the car and its load.

In general therefore representing the weight upon the boxes of the wheels by W, we shall have the draught arising from the friction of the axle $= P =$

$$\frac{W}{12} \times \frac{d}{2r}$$

To adduce a particular case, let $\frac{d}{2r} = \frac{1}{19}$ and weight of load and body of car = lbs 2640 then

$$P = \frac{2640}{12} \cdot \frac{1}{19} = \overset{\text{lbs.}}{11\tfrac{1}{7}}$$

The amount of draught here illustrated is however not perfectly accurate, because independently of the pressure of the weight of the car and its load upon the axle there is an additional pressure on it, occasioned by the draught itself.

To determine then the axle friction perfectly and in a more general form, let us refer to Fig. (26) in which *WSS* represents the wheel supported upon the axle *Mm* and to which the power *P* is applied at *W*.

It is necessary perhaps here to premise that the fractions $\frac{1}{12}$, $\frac{1}{18}$. &c., which express the friction of one surface rubbing on another, also represent the sine of an angle called the "angle of friction" or "limiting angle of resistance," and that the direction of the resistance between all rubbing surfaces is always inclined at the limiting angle of resistance to the perpendicular or normal at the point of contact. Thus in the present instance mR being inclined to mW at an angle $RmW =$ the limiting angle of resistance, mR will be the direction of the resistance of the surfaces at the point m to motion.

From the centre of the axle, O, draw OP parallel to mR, and mn parallel to WP.

Then the effect of the power at W is to its effect at m to create motion round the centre O, as Ow is to $Om :: r : \frac{1}{2}d$. Consequently the effort of P when referred to m will be

$$P \times \frac{2r}{d}$$

But the weight or pressure acts in the direction mO, the effort of P in the direction nm, and the resistance in the direction On; and as these forces are in equilibrio when the surfaces of contact are in a state bordering upon motion, they will be represented in quantity as well as direction by the lines mO, nm, and On; hence

$$Om : nm :: W : P \times \frac{2r}{d}$$

$$\text{and } P \times \frac{2r}{d} = W.\frac{nm}{Om}$$

$$\therefore P = W.\frac{nm}{Om}.\frac{d}{2r}$$

But $\frac{nm}{Om}$ = tangent of the angle nOm ($= RmW$) = tang. of limiting angle of resistance. Consequently representing the limiting angle of resistance by A, we have

$$P = W.\frac{d}{2r} \times \text{tangent } A \ldots\ldots (1)$$

This expression fully involves the increased friction which is due to the increased pressure brought on the axle by the power itself.

The following table shews the sines and tangents of those angles which usually occur in the determination of the draught attributable to the friction of the axles of the vehicle.

Angle.	Sine of Angle to Radius 1.	Tangent of Angle to Radius 1.
1° 55′	$\frac{1}{30}$	.03346
2° 07′	$\frac{1}{27}$	.03696
2° 18′	$\frac{1}{25}$	.04016
2° 30′	$\frac{1}{23}$	.04366
2° 52′	$\frac{1}{20}$	.05007
3° 11′	$\frac{1}{18}$	.05562
3° 35′	$\frac{1}{16}$	.06262
4° 02′	$\frac{1}{14}$	.07197
4° 47′	$\frac{1}{12}$	.08368
5° 45′	$\frac{1}{10}$	.10069
7° 11′	$\frac{1}{8}$	.12603

The resistance to *rolling* upon a level road is owing to two causes either of which or both may be continually in operation. They are, the irregularities of surface over which the wheels must pass and the yielding of that surface beneath the weight.

If neither of these causes of resistance existed the wheel once set rolling upon such a perfect road would continue for ever to move but for the action of the atmosphere, and the less of them a roadway presents the more nearly will it approach to perfection. The road which above all others is the most free from these causes of resistance is the iron railway supported upon continuous bearings, and consequently it is the most perfect description of road with which we are acquainted.

The draught occasioned by irregularities of surface may be simply illustrated thus,

If *R*, (Fig. 27) represents a stone or obstacle over which the wheel has to pass, the whole load which may be supposed to be concentrated in the centre *O* must be elevated the height *WT* of the obstacle and let down again at the other side; in fact it will at slow velocities describe the arch of the circle *OHP* instead of the level line *OP*, along which it would have moved if there were no obstruction. The power *P* which necessarily must be applied in order to originate motion over the obstruction, will act in the direction *OP*, the weight (*W*) of the load in the direction *OT*, and the resistance in the direction

RO. Draw TR parallel to OP and denoting the height of the obstacle by h, then from the equality of moments

$$OT : TR :: W : P$$

$$\therefore P = W.\frac{TR}{OT}$$

but $OT = r - h$, and $TR = \sqrt{2rh - h^2}$,

$$\therefore P = W.\frac{\sqrt{2rh - h^2}}{r - h}$$

Now let us see what is the force a horse must exert to draw his car loaded with one ton weight over an obstacle but 2 inches high. Suppose $r = 27$ inches, and the weight of the car 760lbs. Then the weight upon one wheel

$$= \frac{2240 + 760}{2} = 1500^{\text{lbs.}} = W,$$

$$\therefore P = 1500 \times \frac{\sqrt{108 - 4}}{25} = 612 \text{ lbs.}$$

No horse could exert so great a force as 612 pounds;[*] therefore it would be impossible for him to draw the car from a state of rest over such an obstacle. To surmount then such obstructions, the occurrence of which is by no means rare, the load and car must previously have a momentum, which aided by the effort of the horse would be sufficient to overcome the resistance presented. For meeting these contingencies let us determine what this minimum velocity must be.

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[*] For the exact measure of a Horse power see the subsequent part of this Chapter.

Retaining the previous notation and representing the required velocity by *V*, we see that the least value of *V* must be such that, when the centre of the wheel after having passed through the space *OpH* (see Fig. 28) and been acted upon in its course by the effect of gravity in opposition to the draught will have a volocity $= o$. We also see that the velocity it would retain at any point *p* is equal to that which it had at *O*, diminished by the velocity which would be generated in the space *Op* by the force of gravity in opposition to the force of draught.

Now as soon as the wheel meets the obstruction and further motion is about to ensue, it is clear that the direction of motion will be changed from the level line OP to the tangent OS drawn at right angles to OR. Hence making hN perpendicular to OS and $Oh = l$, we have the initial velocity in the direction $OS = V \times \frac{ON}{Oh}$

$$= V \times \frac{OT}{OR}, \text{ from similar triangles,}$$

$$= V \times \frac{r-h}{r} \dots\dots\dots\dots\dots\dots (2)$$

Let us denote the velocity lost at any point p by v, any line px by y, Hx by x, Op by s, & $16\frac{1}{12}$ feet by m. Then F being any accelerative force, we have from Mechanics

$$vdv = 2mFds$$

$F =$ force of gravity $- P \div W$. And at any point p the force of gravity $= W \times \frac{px}{pR} = W. \frac{y}{r}$,

$$\therefore F = \frac{y}{r} - \frac{P}{W}$$

$$\therefore vdv = 2m \times \left\{ \frac{y}{r} - \frac{P}{W} \right\} ds$$

but $ds = -\dfrac{r}{y}\,dx$

$$\therefore vdv = -2m \times \left\{1 - \frac{P}{W}\cdot\frac{r}{y}\right\} dx$$

Substituting value of $y = \sqrt{2rx - x^2}$

$$vdv = -2m \times \left\{1 - \frac{P}{W}\cdot\frac{r}{\sqrt{2rx - x^2}}\right\}dx$$

$$\text{and } \frac{v^2}{2} = -2\,m \times \int_0^h\left\{1 - \frac{P}{W}\cdot\frac{r}{\sqrt{2rx - x^2}}\right\}dx$$

Integrating between the limits 0 and h, and observing that when $x = h$, $v = 0$ & *arc Op*, $= 0$

$$\frac{v^2}{2} = 2m\left\{h - \frac{P}{W} \times arc\ OpH\right\}$$

$$(3) \ldots\ldots v = 2\sqrt{m} \times \left\{\mathrm{h} - \frac{P}{W}\cdot arc\ Oph\right\}^{\frac{1}{2}} = \text{the}$$

velocity lost at the point H.

Now from the nature of our question we must have $V.\dfrac{r-h}{r} - v = 0$. Substitute then the value of v obtained in last equation, and

$$V.\frac{r-h}{r} - 2\sqrt{m} \times \left\{h - \frac{P}{W} arc\ OpH\right\}^{\frac{1}{2}} = 0$$

$$\therefore\ V = \frac{2r\sqrt{m}}{r-h} \times \left\{ \mathrm{h} - \frac{P}{W}.\ arc\ OpH \right\}^{\frac{1}{2}}$$

This value of V is obtained on the supposition that the power althrough had acted in the most favourable direction for draught, that is in a tangent to the curve.

Suppose $h = 2$ inches or 0.1666 feet, $r = 27$ inches and $\frac{P}{W} = \frac{200}{3000} = 0.0666$; then *arc* $OpH = 0.87$ feet

$$\therefore\ V = \frac{54\sqrt{16\frac{1}{12}}}{25} \times \sqrt{0.1666 - 0.0666 \times 0.87}$$

$= \frac{54}{25} \times \sqrt{1.7466} = 2.85$ feet ꝑ' second or 1.9 miles per hour. And if the horse exerts his whole effort of 200lbs. on but the one wheel

$$\frac{P}{W} = \frac{200}{1500} = \frac{2}{15}, \text{ and}$$

$V = \frac{54}{25} \times \sqrt{0.8138} = 1.944$ feet ꝑ' second or 1.3 miles ꝑ' hour.

Thus we see how necessary it is that the velocity of a horse drawing his usual load of one ton upon an ordinary road should not be less than a certain speed, say $1\frac{1}{3}$ miles per hour or so, in order that he may be able to proceed on his journey and not be brought to a stand still; for upon our roads, as they are commonly repaired, stones of 2 inches high are to be met with almost continually.

Besides the limit of the velocity of the horse, two other matters of consideration are brought to our notice by this inquiry, namely the loss of power occasioned by such obstructions and the injury which a road suffers from the passage of a heavy load over them.

It is clear that whatever tends to increase the draught must also contribute to the increase of the wear and tear of the road itself, for the horses feet must press with a greater force upon the road when he has to exert a greater power. The shocks too of a loaded machine falling from the tops of all such inequalities assist far more to cut the road into ruts and holes and to crush the materials than most persons imagine. If a road were smooth, its wear from wheels would be trifling indeed, as can be inferred from the table page (76.) Stone in itself is so inelastic that it is one of the worst substances in nature to withstand percussion. Thus the strongest piece of stone supported at each end is easily broken by a comparatively light weight let fall from a small height upon it.

If the velocity and momentum of a machine were not diminished by its passage over an unyielding obstacle, it is evident no increase of draught would follow from a repetition of such obstructions; but this in any instance will not be the case.

Let V denote the velocity of the machine before meeting the obstacle. Now the velocity in the direction OS (Fig. 28) was ascertained to be $V \times \frac{r-h}{r}$, (Equation 2), on the supposition that the wheel and the resisting substance at R were both inelastic (which is the view most favorable to draught); and the load will retain this velocity when it arrives at P, but its direction will then be SP. Again, a further diminution of velocity will ensue by the change of its direction from the incline SP to the level OPP, in the proportion of $SP : hP ::$ Radius : cos. $hPS = TOR :: r : r - h, \therefore r : r - h :: V.\dfrac{r-h}{r}$: horizontal velocity retained at $P = V.\dfrac{\overline{r-h}^2}{r^2}$

Again the force accumulated in a body moving at any velocity is the same as the amount of work that should be expended in lifting an equal weight a certain height through which the body should fall in order to acquire that velocity. We may therefore represent the accumulated force in the weight of the machine before meeting the obstruction by WS and that retained afterwards by WS_1, where S is the height due to the velocity V and S_1 that due to the velocity $V.\dfrac{\overline{r-h}^2}{r^2}$. The accumulated force lost will therefore be

$$W.(S - S_1) \ldots\ldots\ldots\ldots (4)$$

Now from the laws of falling bodies

$$4ms = v^2, \text{ and } s = \frac{v^2}{4m}$$

in which v = any velocity acquired, s the space passed through and $m = 16\frac{1}{12}$ feet. Therefore

$$S = \frac{V^2}{4m}$$

and $S_1 = V^2 \times \frac{(r - h)^4}{4mr^4}$; consequently the accumulated force that was lost is

$$\frac{WV^2}{4m} \times \left\{1 - \frac{(r - h)^4}{r^4}\right\} = \frac{WV^2}{m} \times \frac{h}{r} \text{ nearly} \ldots (5)$$

Thus we find that while the load is moved horizontally through the space OP it will have lost as much momentum as would raise it vertically through the height $h \times \frac{V^2}{mr}$. If this deficiency of momentum be supplied by the increased exertion of the horse for the purpose of maintaining motion, we must therefore conclude that the additional draught above that required upon a level is represented in parts of the entire weight by $V^2 \times \frac{h}{2lmr}$.

But $2l = 2\sqrt{2rh - h^2}$,

$$\therefore \text{ additional draught} = \frac{V^2 h}{2mr\sqrt{2rh - h^2}}$$

$$= \frac{V^2}{2mr} \times \sqrt{\frac{h}{2r - h}} \ldots\ldots\ldots\ldots (6)$$

A more accurate but nearly the same conclusion may be summarily arrived at thus:

Let p = the additional draught which is supposed to act constantly so as to preserve the same average velocity, or that the curve *OHP* should be described in the time $\frac{l}{V}$, and that the body should have the same horizontal velocity at *P* that it had at *O*. The accelerative force *F* will consequently $= \frac{p}{W}$. We here denote the whole length *OP* by l instead of $2l$ as heretofore. Now the velocity in the direction *OS* was $V . \frac{r - h}{r}$

therefore the velocity at P in the direction SP will be $V.\frac{r-h}{r}$ + the velocity generated by the accelerative force $\frac{p}{W}$ in the time $\frac{l}{V}$

$$= V.\frac{r-h}{r} + 2m\,\frac{pl}{WV}$$

And the horizontal velocity at P is

$$\frac{r-h}{r} \times \left\{ V.\frac{r-h}{r} + \frac{2mpl}{WV} \right\} = V$$

$$V^2.\frac{\overline{r-h}^2}{r^2} + \frac{2mpl}{W}.\frac{r-h}{r} = V^2$$

$$\frac{r-h}{r}.\frac{2mpl}{W} = V^2 \times \left\{ 1 - \frac{\overline{r-h}^2}{r^2} \right\}$$

$$2mpl = WV^2.\left\{ \frac{r}{r-h} - \frac{r-h}{r} \right\} = WV^2 \times \frac{2h}{r-h}\text{ nearly}$$

$$\therefore p = \frac{WV^2}{ml}.\frac{h}{r-h} = \frac{WV^2}{2m.(r-h)} \times \sqrt{\frac{h}{2r-h}}\ ..(7)$$

Now suppose $V = 5$ feet ⅌ second or 3½ miles per hour and that all the other dimensions are the same as those hitherto given, we shall have the increased draught in parts of the weight moved from a recurrence of obstacles 2 inches high, equal to

$$\frac{25}{32.16 \times 2.084} \times \sqrt{\frac{2}{54-2}} = \frac{1}{13.65}$$

or the draught will be the same as if the machine were placed upon a plane rising 1 in $13\frac{2}{3}$.

From these equations it seems that the draught on a road, whose surface presents a number of unyielding and projecting obstacles, varies directly as the square of the velocity and inversely as the square root of the cube of the size of the wheel.

The draught upon an irregular surface however must be much more than that which we have ascertained in all cases when the velocity of motion is considerable, because there is no substance perfectly inelastic; and therefore after striking the obstacle the wheel will rebound backwards from the obstacle with a velocity proportionate to the relation of the forces of *impact* and *restitution* referable to the elasticities of the wheel and the material of the obstruction.

Moreover, the obstacle when struck will in many cases slide to some extent and thereby weaken the momentum which yet has to enable the load to surmount that obstacle as if it had been stationary. Again, when the velocity is but little more than that which is regarded as moderate speed, and although we omit the consideration of the partial elasticities of the wheel and obstacle, the axle of the vehicle and therefore the load or weight will describe the parabola OH_1P_1, (Fig. 29) instead of proceeding along the curve of the circle OHP, which it would do if the velocity were slow, the circle and parabola having the common tangent OS; but if elasticity be considered it will proceed along the parabola OH_2P_2 whose tangent OS_2 is inclined to OS_1 at an angle the sine of which is the force of *restitution* ÷ the force of *impact*.

These investigations are very interesting to the engineer in particular; but the limits of our work necessarily prevent us from going as far into them as some of our readers might wish, As far as we have gone the necessity must be obvious of having the road smooth and the stones broken to a small size. It is also perceptible how much the adherence to these maxims will contribute to the diminution of the wear and tear of the road itself. For let it be borne in mind, that besides the palpable increase of injury which the road must suffer by the percussive descents of the wheel and additional effort of the horse upon a surface repaired with large sized stones, compared with that upon the like surface maintained with small sized stones, we also know that the momentum of the load is checked more in the former case than in the latter and that the check increases its injurious effect upon the road itself.

It is true that mounting the body and load of a car on springs will contribute to a certain extent towards reducing the draught over a surface which presents a number of unyielding obstacles to the wheels; for while the wheel is suddenly elevated over the obstacle, yet from the yielding of the springs, the body and load will not be raised so high. With slow velocities however, the body of the machine as well as its load will be elevated and depressed just as often and as much as the wheel, and consequently the draught will not be diminished by the use of springs.

Besides the draught upon a level common road occasioned by a rough surface in addition to the friction of the axles of the vehicle, which latter is at all times to be encountered, we have adverted to another species of resistance, namely the resistance to rolling produced by the passage of the wheels through a soft yielding surface.

To a great extent upon the best common road as upon the worst, the resistance to rolling is attributable to the continual displacement of a portion of the material owing to its inelasticity, which while it allows that material to exert a pressure against the fore part of the wheel will not permit it to rise behind and thereby propel the wheel by its reaction, as would be the case if the material were elastic. Thus the draught upon a sandy, clayey, or muddy surface, although the vehicle still moves in a level line, is much more than if it were upon a hard unyielding surface.

The more a wheel sinks into such surfaces, the greater will be the draught; and if we suppose the degree of elasticity of the yielding materials of the surface and the resistance at different specific depths to be known, we can calculate the whole effect of their action upon the wheel and the force that is required to displace them in the progressive movement of the vehicle.

Referring to Fig. 30, let us suppose *RK* to be the surface of a muddy road and *ZWk* a hard substratum to which the wheel *WRH* will compress the mud in its motion towards *K*. Let us further suppose that the draught or power acts in the direction *OP* parallel to the horizontal line *ZWk*, and that the mud *ZW* once rolled over and compressed has no tendency to rise again.

Now it is evident that the entire weight of the wheel and its load is supported by the mud *WR*, and that the surface at any point between *W* and *R* will be pressed with a greater or lesser portion of the weight according as it is nearer or farther from the lowest point *W* of the wheel.

Take any element of the surface of the mud under compression as *Xi*, draw *Xa*, *ig* perpendicular to *TR* and *XS*, *im* perpendicular to *WO* Let the height *WS* of the point *X* above the lowest part of the wheel be represented by x, and the horizontal distance *SX* from the same point by y, the entire depth of the rut $= h$, and the length $TR = l$. Now the mud at *X* has been compressed through the height *TW*; if then we assumed that the resistance to compression varied simply as the depth compressed or as *aX* then the pressure, say ⅌ square inch, at *X* would be to that at W as the lines $aX : TW :: h - x : h$. Representing the pressure ⅌ square inch at W by f, then the pressure ⅌ square inch at X will be $f \times \frac{h-x}{h}$.

Again, i being very near to X, we may suppose the pressures to be alike in the two places; therefore the entire pressure upon the part Xi of the mud in the direction XO will be $Xi \times f \times \frac{h-x}{h}$

But the pressure in the direction XO : that in the direction $Xa :: Xi : ag$; hence the vertical pressure upon $Xi = ag \times f. \frac{h-x}{h}$. And as the sum of the vertical pressures upon all the elements of the surface $WR = W$ or the weight of the wheel and its load, we have therefore.

$$W = \frac{f}{h} \times \int_{h}^{o} (h-x)\, dy, = \frac{f}{h} \times A, \text{ (where } A$$

represents the area WTR)

$$\therefore f = W \times \frac{h}{A}$$

Again, $y = \sqrt{2rx - x^2}$, $\therefore dy = \dfrac{r - x}{\sqrt{2rx - x^2}} dx$

But the vertical pressure upon the element of surface Xi was ascertained to be $f.\dfrac{h - x}{h} dy$; consequently substituting values of f and dy, the vertical pressure on Xi

$$= \frac{f}{h} . \frac{\overline{h - x} \times \overline{r - x} . dx}{\sqrt{2rx - x^2}} = \frac{W}{A} . \frac{\overline{h - x} . \overline{r - x}}{\sqrt{2rx - x^2}} . dx$$

Now when the wheel is in a state bordering upon motion, the element of draught, the vertical weight upon the element of surface Xi, and the resistance of that surface, will be severally represented in quantity and direction by the lines SX, SO, and XO. Therefore $dP = \dfrac{SX}{OS} \times$ vertical weight upon the element of surface $Xi = \dfrac{\sqrt{2rx - x^2}}{r - x} . \dfrac{W}{A} . \dfrac{\overline{h - x} . \overline{r - x}}{\sqrt{2rx - x^2}} . dx$

$$= \frac{W}{A} \times \overline{h - x} . dx$$

and $P = \dfrac{W}{A} \times \displaystyle\int_h^0 (h - x) . dx = W . \dfrac{h^2}{2A}$

Now, to find the value of P in simpler terms than those of the depth and area of that portion of the wheel which is constantly immersed in the rut, we may substitute zhl for A in the last equation, z being the ratio of the segmental area WTR to that of its circumscribing parallelogram, then $P = W\dfrac{h}{2zl} = W.\dfrac{h}{2z\sqrt{2rh-h^2}}$

$$=\frac{W}{2z}\times\left\{\frac{h}{2r}+\frac{h^2}{4r^2-2rh}\right\}^{\frac{1}{2}}=\frac{W}{2z}.\sqrt{\frac{h}{2r}}\times\left\{1+\frac{h}{2r-h}\right\}^{\frac{1}{2}}$$

$$=\frac{W}{2z}\times\sqrt{\frac{h}{2r}} \text{ very nearly.}$$

But $h = r - \sqrt{r^2-l^2}$, and $\dfrac{h}{r} = 1 - \sqrt{1-\dfrac{l^2}{r^2}}$

$$\therefore \sqrt{\frac{h}{2r}} = \frac{1}{\sqrt{2}}\times\sqrt{1-\sqrt{1-\frac{l^2}{r^2}}}$$

$=\dfrac{1}{2}\times\left\{\sqrt{1+\dfrac{l}{r}}-\sqrt{1-\dfrac{l}{r}}\right\}$ by the ordinary mode of extracting the square root of Binomial quadratic surds. Expanding this last expression,

$$\sqrt{\frac{h}{2r}} = \frac{1}{2} \times \left\{ \begin{array}{l} + \left\{ 1 + \frac{1}{2} \cdot \frac{l}{r} - \frac{1}{8} \cdot \frac{l^2}{r^2} + \frac{1}{16} \cdot \frac{l^3}{r^3} - \&c. \right. \\ - \left\{ 1 - \frac{1}{2} \cdot \frac{l}{r} - \frac{1}{8} \cdot \frac{l^2}{r^2} - \frac{1}{16} \cdot \frac{l^3}{r^3} - \&c. \right. \end{array} \right.$$

$$= \frac{1}{2} \times \left\{ \frac{l}{r} + \frac{1}{8} \cdot \frac{l^3}{r^3} + \frac{5}{64} \cdot \frac{l^5}{r^5} + \frac{35}{640} \cdot \frac{l^7}{r^7} + \&c. \right.$$

But as l is always less than r we may omit all the terms except the first in an approximation, then

$$\sqrt{\frac{h}{2r}} = \frac{l}{2r}$$

$$\therefore P = \frac{W}{2z} \times \sqrt{\frac{h}{2r}} = W . \frac{l}{4zr}$$

For small arcs $z = \frac{2}{3}$ or a little more.

$$(8) . . \therefore P = W . \frac{3l}{8r} = \frac{3\,W}{8} \times \frac{\text{Length immersed}}{\text{Diameter of wheel}},$$

the Draught of a vehicle through such a yielding surface. Let us take the case of a car loaded with a ton weight and sinking one inch into a stiff muddy surface; $W =$ ℔s 3000, $r = 27$ inches,

$\therefore l = 7.28$ inches. Hence the draught will be

$$P = 3000 \times \frac{7.28}{27} \times \frac{3}{8} = 303\tfrac{1}{4} \text{ lbs.}$$

If the depth of sinking were half an inch the draught would be 215lbs, and if the vehicle sunk but quarter of an inch its draught would be 152lbs.

However when the mud is of a soft or fluid-like consistency it will not offer so great a resistance as that derived from the equation (8); because the law of resistance to compression will vary as a higher power of the depth compressed. But the general investigation is similar in every instance to that above given, and wholly independent of the velocity of the vehicle.

Under the supposition that the resistance to compression varied as *the depth* compressed, it is evident that as long as the weight and description of surface rolled over were the same, although the wheels were of different sizes, the area of the immersed section of the wheel must be the same or constant.

Now $h = \frac{l^2}{2r}$ nearly, $\therefore lh = \frac{l^3}{2r}$; and as A is constant $lh \propto 1$, $\therefore \frac{l^3}{2r} \propto 1$; and $l \propto \sqrt[3]{r}$. But from equation (8) $P \propto \frac{l}{r}$

$$\therefore P \propto \frac{\sqrt[3]{r}}{r} : \frac{1}{r^{\frac{2}{3}}}.$$ Or the draught will vary inversely as the cube root of the square of the size of the wheel, or little more than the inverse of the height of the wheel.

To whatever cause the draught occasioned by the surface of the road is attributable, whether it be the roughness of a hard stony surface, or the sinkage in a soft surface or both, it is quite clear that the vehicle will be under precisely the same circumstances in all cases as if an unyielding obstruction *R* (Fig. 31) of a certain height were continually presented to the wheel.

The height WT of R must be such that

$$OT : TR :: W : \text{Friction of rolling.}$$

Now if there were no friction between the box of the wheel and the axle, the resistance would be in the direction RO; but as some friction exists between them, the direction of resistance must be inclined at a greater angle to the vertical. Again the direction of the resistance between the surfaces of the box and axle being inclined to the radius at an angle equal to the *angle of friction* between these surfaces, if we draw RV so that $OmV = A =$ this *angle of friction*, we shall have $RV =$ the direction of the entire resistance.

Make the vertical AB to represent the weight W, draw DE in the direction of draught, and AD parallel to RV; then as the wheel is supposed to be in a state bordering upon motion, we shall have the draught P obtained as follows from the equality of moments,

$$P = W \times \frac{BD}{BA} = W \times \frac{\sin. BAD}{\sin. BDA}$$

But $BAD = RmW$, and $BDA = ABE - BAD$

$$= ABE - RmW$$

$$\therefore P = W \times \frac{\sin. RmW}{\sin. \{ABE - RmW\}}$$

Let R represent the angle ROW, r the radius of the wheel, a the angle ORm, i the angle of inclination of the traces to the plane of the road, and $\pi = 180^\circ$; then $RmW = R + a$, $ABE = \frac{\pi}{2} + i$, and $ABE - RmW = \frac{\pi}{2} + i - R - a$

$$= \frac{\pi}{2} - \left\{R + a - i\right\}; \text{ also}$$

$$\sin. \frac{\pi}{2} - \left\{R + a - i\right\} = \cos. \left\{R + a - i\right\}$$

$$\therefore P = W \times \frac{\sin. \{R + a\}}{\cos. \{R + a - i\}} \text{ .... (9)}$$

The best inclination of the traces to the plane of the road is such as gives P a minimum in last equation. This evidently takes place when the denominator of the expression is the greatest, which ensues when

$$\cos. \{R + a - i\} = 1, \text{ or } R + a - i = 0$$

$$\text{and } i = R + a$$

If i or the inclination of the traces to the plane = 0, then

$$P = W \times \frac{\sin. \{R + a\}}{\cos. \{R + a\}} = W \times \text{tang.} \left\{ R + a \right\} \text{(10)}$$

$$= W \times \frac{\text{tang. } R + \text{tang. } a}{1 - \text{tang. } R \times \text{tang. } a}$$

From construction, sin. of angle of friction of rolling = tangent of R, and

$$mO : RO :: \sin. a : \sin. OmW = \sin. A$$

$$:: \text{tang. } a : \text{tang. } A.$$

$$\therefore \text{tang. } a = \text{tang. } A \times \frac{mO}{RO} = \text{tang. } A \times \frac{d}{2r}$$

Now let R_1 = the angle of friction of rolling, consequently

$$P = W \times \frac{\sin. R_1 + \text{tang. } A. \dfrac{d}{2}}{1 - \sin. R_1 \times \text{tang. } A. \dfrac{d}{2r}} \text{ .. (11)}$$

M. Morin in his "Experience sur le Tirage des Voitures faites en 1837 et 1838," deduces the following conclusions.

1st. The draught is directly proportional to the load and inversely proportional to the diameter of the wheel.

2nd. Upon a paved or a hard Mc. Adamised road the resistance is independent of the width of the tire when it exceeds from 3 to 4 inches.

3rd. At a walking pace the draught is the same, under the same circumstances, for carriages with springs and without them.

4th. Upon hard Mc. Adamized and upon paved roads the draught increases with the velocity; the increments of draught being directly proportional to the increments of velocity above the velocity of 3.28 feet per second or 2¼ miles ⅌ hour. The equal increment of draught, thus due to each equal increment of velocity is less as the road is more smooth and the carriage less rigid and better hung.

5th. Upon soft roads of earth, or sand or turf, or roads fresh and thickly gravelled the draught is independent of the velocity.

6th. Upon a well made and compact pavement of hewn stones, the draught at a walking pace is not more than three-fourths of that upon the best broken stone road under similar circumstances; at a trotting pace it is equal to it.

7th. The destruction of the road is in all cases greater as the diameter of the wheels are less, and it is greater with carriages not having than with those having springs.

It is to be remarked that all these deductions of M. Morin are in perfect accordance with our previous investigations.

We find in the second report of the select committee of the House of Lords 1833 upon Turnpike Road Trusts, Mr. Macneill has given the following empirical formula for the draught on common roads.

$$P = \frac{W + w}{93} + \frac{w}{40} + cV$$

Here W = weight of waggon, w = the load, V = the velocity in feet per second, and c = a constant quantity, which will depend on the surface over which the waggon is drawn.

He ascertained the value of c for different surfaces as follows.

$c = 2.$ For a timber surface.
$= 2.$ For a paved road.
$= 5.$ For a well made broken stone road in a dry state.
$= 8.$ For the like surface covered with dust.
$= 10.$ For the same, wet and covered with mud.
$= 13.$ For a gravel or flint road when wet.
$= 32.$ For the same very wet and covered with mud.

The draught of a machine at moderate volocities upon a road made upon an elastic substratum such as bog, &c. will not be greater than it would be were the substratum perfectly hard and unyielding; because as much as the wheel seems to be retarded by the rise in front so much will it be assisted by the reaction of the same behind. Mr. Barlow details an experiment in his work upon the strength of materials, page 470, one of the results of which goes directly to confirm this fact.

He placed a loaded model carriage upon two bars each 30 inches long of drawn steel $\frac{1}{4}$ inch by $\frac{1}{8}$. The load with the carriage weighed 134 ounces. The bars being supported for their whole length by well planed pieces of wood so that they should not bend, the friction of the carriage was found to be 5 ounces. The pieces of wood were then removed and the friction at the lowest point of the curve, or midway between the supports, was found to be 5 ounces as before and no more, although the deflection of the bars was nearly half an inch.

We may in perfect safety assume, with respect to the draught of any one load upon a road with a well drained bog substratum, that such substratum is perfectly elastic; because the bog cannot suffer any appreciable amount of permanent compression from the passage of the one load only.

Before leaving the subject of draught upon level roads, we deem it useful to advert generally to the conclusions of some of our investigations.

We perceive the draught is owing, as was before stated, to the friction of the axles and the friction or resistance of rolling.

The friction of the axles is invariable as to the mode of its action and will have to be always encountered.

The resistance to rolling must also be constantly overcome, and is of two sorts, either or both of which may have place even upon the same road. Thus the resistance to rolling may arise from a soft surface whether smooth or irregular or from a hard surface, if it be irregular.

We have seen the effects which variations in the velocity of motion and size of the wheels as well as the adoption of springs would have upon the increase or reduction of each of these species of resistance, and we are aware of the best and most modern experiments in which all these circumstances simultaneously cooperate to affect the draught.

Comparing theoretical investigation with experiment, in the first place, we have said that the draught is not diminished by the use of springs when the velocity is so slow as to permit the body of the vehicle to be elevated and depressed just as much as the axle; and this corresponds with experiments. We have also stated that when the vehicle moves over an even soft surface, its draught ought not be affected by the velocity. This too corresponds with the experiments of M. Morin, but it is at variance with the views of Mr. Macneill, for in his formula the increments of traction in such cases are dependent upon the velocity.

When the machine passes over a *hard* irregular surface, we have ascertained that the draught should increase with the velocity; and this deduction is borne out by experiment. We have deduced (Equa. 5) the variation of the draught to be as the square of the velocity, but there is a seeming discrepancy between this conclusion and the results of experiments made under apparently analagous hypotheses which would regulate the increments of traction by proportional increments of velocity. However we must consider that the experiments of M. Morin and others were made upon roads said to be hard yet not so in fact, and with elastic machines; whereas had the experiments been conducted upon a perfectly unyielding surface and with a rigid and inelastic machine, we have no doubt that the draught should vary as the square of the velocity; and we may conclude that according as the machine and rough roadway approach a state of inelasticity the more nearly will the draught correspond with this law of variation. Every road presents a different description of surface, and if upon one the draught was not at all affected by the velocity or varied as V^0 owing to its softness and regularity, and upon another it varied as V^2 owing to its hardness and roughness, surely as there are many intermediate descriptions of surface between these extremes so also must the draught upon them vary as some intermediate power, between 0 and 2, of the velocity. Therefore in general the resistance to rolling must vary as V^n, in which n is the constant suitable to each particular surface and always lying between 0 and 2; and any accurate empirical expression for the draught upon roads must have V^n as one of its terms.

At any rate the draught is always dependent upon the value of the angle R in Equation (10) and we have found this angle to be at slow velocities generally as follows:

Description of Road.	Value of R.			Tang. R.
	°	′	″	
Upon an Iron Railway having bearings 3 feet apart	0	1	10	.00034
Upon an Iron Railway having bearings 6 feet apart	0	2	10	.00063
Upon an Iron Tramway	0	4	15	.00121
Do. Cut Stone Trackway	0	12	54	.00378
Do. Timber Trackway	0	12	54	.00378
Do. Timber Paving	0	39	24	.01144
Do. Close firm Stone Paving	0	50	00	.01460
Do. Very good broken stone Road.	1	30	00	.02618
Do. Ordinary broken stone Road.	2	1	40	.03540
Do. The same in bad order	3	35	00	.06260

The effect of an inclined roadway is such that it always increases the mechanical draught when ascending and diminishes it when descending.

Considering this subject firstly as if there were no rolling or rubbing friction, let us refer to Fig. (32). WwR is the angle of inclination of the plane to the horizon which we shall denote by s, DE the direction of draught is parallel to Rw, EA is perpendicular to the horizon and represents the weight, and RO and AD are perpendicular to the plane and parallel to the direction of its resistance. Now the power, weight and resistance being in equilibrio as motion is about to ensue, they are represented by the lines DE, AE, and AD consequently

$$P = W \times \frac{DE}{AE}$$

But as the triangles AED and wRt are similar

$$\frac{DE}{AE} = \frac{tR}{wR} = \sin. s$$

$$\therefore P = W. \sin. s \ldots\ldots\ldots (12)$$

This expression represents the force of gravity only on any body, flat or round, placed upon the plane wR, and acting in the direction of the descent of the plane.

Secondly, if the friction at the tire and axle be taken into consideration, let us adopt the notation of Equa. (10), and suppose *tw* $W = s$ the angle of inclination of the plane to the horizon. (See Figs. 32 & 33.)

In this case as before the draught is in the direction DE, the resistance in the direction RV and AD, and the weight in the direction OG and BA; and when the wheel is in a state bordering upon motion, these forces are represented in quantity as well as direction by the lines DB, AD, and BA. Therefore

$$P = W \times \frac{BD}{BA} = W \times \frac{\sin.\ BAD}{\sin.\ BDA} =$$

$$= W \times \frac{\sin.\ RmG}{\sin.\ \{ABE - RmG\}}$$

But $RmG = s + R + a$, $ABE = \frac{\pi}{2} + i + s$,

$ABE - RmG = \frac{\pi}{2} - (R + a - i)$, and $\sin.\ \{ABE - RmG\} = \cos.\ (R + a - i)$ therefore ascending,

$$P = W \times \frac{\sin.\,(s + R + a)}{\cos.\,(R + a - i)} \ldots\ldots\ldots(13)$$

when descending $WS = WR$, and Sv is the direction of resistance, consequently as before

$$P = W \times \frac{\sin.\,RmG}{\cos.\,(R + a - i)} = W \times \frac{\sin.\,(R + a - s)}{\cos.\,(R + a - i)} \;(14)$$

The most favourable value of i in either case is when $\cos.\,(R + a - i) = 1$, or $i = R + a$ as was before ascertained.

If $i = 0$, or the traces act parallel to the plane, then, ascending,

$$P = W \times \{\sin.\,S + \cos.\,S.\,\text{tang.}\,(R + a)\} \;..\;(15)$$

descending,

$$P = W \times \{\cos.\,S.\,\text{tang.}\,(R + a) - \sin.\,S.\} \;..\;(16)$$

We have here to remark that in equation (10) the draught upon a level was $W \times \text{tang.}\,(R + a)$ and in equations (15) and (16) it is $W.\,\cos.\,S.\,\text{tang.}\,(R + a) \pm \sin\,S.\,W$; or the draught upon an incline is that upon a level × the cos. of the inclination + or − the force of gravity, the positive sign being adopted when the draught is upwards and the negative when the draught is down the plane. In ordinary cases cos. S is nearly 1; and tang. $(R + a)$ will very nearly $=$ tang. R + tang a = tang. R + tang. $A \times \frac{d}{2r}$. Now with an ordinary waggon $A = 4^\circ\ 47'\ 00''$, and tang. $A = .084$; also $\frac{d}{2r} = \frac{1}{18}$. And upon an ordinary broken stone road $R = 2^\circ\ 1'\ 40''$ and tang. $R = .0354$. Therefore the draught of one ton upon an ordinary level road is

$$P = 2240 \times \left\{0.0354 + \frac{0.084}{18}\right\} = 90\text{lbs. nearly,}$$

$$= \frac{W}{25} \text{ very nearly.}$$

Upon a rise of 1 in 30 the draught is nearly that upon a level + W sin. 3

$$P = 90 + \frac{2240}{30} = 90 + 74\tfrac{2}{3} = 165\text{lbs. nearly}$$

And upon a fall of 1 in 30, the draught will be nearly that upon a level $-\ W \times$ sin. $S =$

$$P = 90 - \frac{2240}{30} = 16\text{lbs. nearly.}$$

Where great accuracy is to be observed in determining the amount of draught, the exact values of sin. and cos. S, and tang. $(R + a)$ must be substituted in the several equations (10), (15), and (16).

In places where a great deal of heavy cartage exists it is oftentimes impossible to avoid inclinations of surface. It then becomes a matter of great importance and sometimes necessity to endeavour by some means or contrivance to compensate for the additional draught that must ensue from the force of gravity upon these ascents.

The mode we should recommend for effecting this object is to construct such a description of surface in itself more favourable to draught, upon the acclivity.

We have seen that the draught is generally expressed upon a level by

$$P = W \times \left(\text{tang. } R + \text{tang. } A \times \frac{d}{2r} \right) \text{ nearly,}$$

and upon an acclivity by

$$P = W. \cos. S. \times \left(\text{tang. } R + \text{tang. } A \frac{d}{2r} \right) + \sin. S. W$$

in which S is the angle of ascent and R the angle of friction of rolling corresponding to any description of surface. Also upon an ordinary broken stone surface tang. $R = .0354$; and with an ordinary machine tang $A \times \frac{d}{2r} = .0046$.

This being so it is clear that without altering the weight W or increasing the draught P we may vary the values of R and S and still have these two equations alike. Under these conditions therefore we have

$$\cos. S \times (\text{tang. } R + .0046) + \sin. S$$
$$= .0354 + .0046 = .04$$

$$\text{tang. } R + .0046 + \text{tang. } S = \frac{.04}{\text{cos. } S}$$

$$\therefore \text{tang. } R = \frac{.04}{\text{cos. } S} - \text{Tan. } S - .0046$$

and tang. $S = .04 - .0046 - \text{tang } R$, very nearly as S will not be a large angle, $= .0354 - \text{tang. } R$ (17) Consequently, as long as the tangent of the angle of rise of the plane is not greater than .0354, the tangent of the angle R, corresponding to any particular description of surface adopted, the draught of the machine upon the acclivity will not be any more than it is usually upon the ordinary level road.

The following Table of uniform draught shews the description of road surface suitable for different acclivities and *vice versa.* It has been calculated from Equation (17) in the following manner.

Suppose that the greatest acclivity for a cut stone track is required, so that the draught on it may not be more than that upon the ordinary broken stone surface without any rise. Here

$R = 0^\circ\ 12'\ 54''$, and tang. $R = .00378$ (See Table page 262). Then substituting value of tang. R in equation (17)

$$\text{tang. } S = .0354 - .00378 = .0316$$

or the angle is an acclivity of 1 in $31\frac{2}{3}$.

TABLE OF UNIFORM DRAUGHT.

Description of Surface.	Rate of inclination.
Ordinary broken stone surface........	Level.
Close firm stone paving	1 in $48\frac{1}{2}$
Timber paving	1 in $41\frac{1}{2}$
Timber Trackway....................	1 in $31\frac{2}{3}$
Cut stone Trackway.................	1 in $31\frac{2}{3}$
Iron Tramway	1 in $29\frac{1}{4}$
Iron Railway........................	1 in $28\frac{1}{2}$

The motive powers at present made use of for the conveyance of vehicles upon roads are the Steam Engine and the Horse.

So much has been written on the Steam Engine as applied to the purpose of locomotion that we could be expected to offer but little that is new on the subject and just as little that would be really useful; especially as the particular description of Steam Engine best suited to common roads and which alone falls within the prescribed limits of our enquiry, remains to this day a subject of dispute. For information on the subject of the Locomotive Steam Engine the Reader is referred to the 2nd Report of the "Railway Commissioners, Ireland," to the work of F. M. G. De Pambour, and the Transactions of the Institution of Civil Engineers, London. However we may be permitted to state, that from all the knowledge which we have been able to collect, it is not likely that the Steam Engine will supersede the Horse in the work of conveying heavy loads at slow velocities upon broken stone roads such as we have at present, since it has been ascertained that the Horse is the more economical machine of the two for such work even upon railways. Experience also justifies the hope that at no distant period Steam Engines of suitable construction will be advantageously employed for the conveyance of passengers along roads of improved formation at quick velocities.

The subject of Horse power is one which we are rather diffident in entering upon, because nearly all that has been heretofore written upon it, is unquestionably very deficient. In every one of the investigations on this subject that have fallen under our observation, the power which the muscles of the horse have to exert for the purpose of overcoming the resistance of his own body is a consideration wholly left out of view; and it is in vain that we look to such investigations for any one general expression of his *total power*, embracing his velocity, his stress available for draught, and the duration of his days work.

In the following few pages it is not pretended that this very interesting subject is treated of in its fullest extent, yet we humbly trust the general principles here developed will upon examination be found more accurate than any hitherto advanced, and that the conclusions deduced cannot fairly be called in question.

If a horse is not overworked his muscles should not be fatigued more at the end of one day than another. The days fatigue then of any given horse when fairly worked should be alike or constant. Let us denote this constant days fatigue by M.

Again, the fatigue which horses suffer for any limit of time, say one hour, is different under different circumstances of speed and stress; and the length of time T hours which he can endure this fatigue each day will evidently be less according as that fatigue is greater, provided M at the end of the day's work remains constant. Representing therefore the fatigue for the limit of time generally by f we have in all cases

$$M = f\,T$$

now f or the muscular exertion expressed in the unit of time depends on two principal elements as we before now said, namely, the stress and the velocity or space through which that stress is exerted during the unit of time. The stress is occasioned by the friction of the animal machine and the Draught of the vehicle which he nraws; and the space passed through in the unit of time is the velocity of motion V. Consequently if we denote the friction of the animal machine by p and the available draught by P we have

$$f = V \times (P + p)$$

Substituting this value of f corresponding to a unit of time in the preceding equation

$$M = TV \times (P + p) \ldots\ldots\ldots (18)$$

This expression involves all the objects of our enquiry; and from it we can obtain the available draught of the horse under all the circumstances of variable velocities and duration of days work or *vice versa* if we know the values of M and p.

Respecting the value of p, it will be evident from a little consideration, that it consists, like the friction of the mechanical machine, of three species of resistances, viz.: the friction of the *joints* of the animal, that occasioned by the yielding of the ground beneath his feet, and the loss of momentum incurred at each Step, similar to what takes place with the vehicle when it meets a projecting obstacle upon a road. To explain the general movement of the horse we shall refer to Fig. (34). It appears that when he is about to move, several parts of his body have a tendency to describe the arches of circles whose centres are his feet and radii the length of his legs, and as he continues to move, those different parts are inclined to describe a succession of such arcs. Thus confining ourselves in the first place to moderate velocities, the path which those parts of the body are inclined to describe is represented by the lines $O\,O_1$, $O_1\,O_2$, $O_2\,O_3$, &c., where O, O_1, O_2, &c. is the lower joint of the *humerus* or the *stifle joint* of the *femur* or thigh, and R, R_1, R_1, &c. the feet of the animal. At a quick pace when the horse trots or gallops, the path described will be so many curves of a parabola. Thus we see that a portion of the momentum must be lost at each step on account of the mechanism of the horse, as his motion will be analagous to that of a wheel going over a number of obstacles, for the momentum in the direction J_1S_1 (Fig. 35), will be less than that acquired in the direction J_1S, and one set of muscles in the descending portion JJ_1 of each step must generate an additional velocity that will compensate in part for this consequent loss, while another set compensates for the remaining part by yielding to the weight of the body in the ascending portion J_1J_2.

It would appear therefore that the resistance from the change of direction of motion which thus takes place at each step must be very considerable (see Equa. 5) and that it is of such a nature as varies directly as the square of the velocity, if we confine ourselves to the consideration of an external agent of locomotion, as that of an external pressure or draught which acts from without any machine moved and thereby maintained in an uniform speed. But in the case of the animal machine the muscles of the bony (principally those adjacent to the *Humerus* and *Tibea)* which are the source of power, are themselves moved forward at the velocity of the horse, and consequently the stress upon them for overcoming this species of resistance will vary but as the velocity.

To give a further proof of our views respecting the muscular power which must be expended in maintaining the momentum we have in the first place to refer to page 240 and to state that the resistance (in the simple acceptation of the term) to uniform motion (no matter by what agency that resistance is overcome) is affected by the same laws in the case of the animal as the mechanical machine, and consequently must vary as the square of the uniform velocity maintained. It was shewn in that part of our work that the *constant pressure* which must be applied to the machine varies as the square of the velocity or V^2 and may be expressed generally by gV^2 in which g represents the constant suited to a particular case which defines the general variation. Now if the agent were an external force, such as a weight passing over a pulley or a steam engine, the work expended in moving the machine a unit of space S is evidently represented by the pressure × the space passed through or $S \times gV^2$. It will also be evident that the *muscular* work of the horse expended in maintaining the like pressure gV^2 on his body will be represented by $gV^2 \times$ the space through which the muscles acted or rather were expanded. Again *cæteris paribus* we know the space through which the principal muscles will have expanded themselves in the passage of the horse over a unit of space, say one mile, varies as the time. But the time $\propto \frac{1}{V}$; therefore the muscular work expended in maintaining a uniform momentum is expresssed by $gV^2 \times \frac{1}{V} = gV$. Consequently the stress or muscular work corresponding to a unit of space generally varies as V or the velocity.

Hence if this stress is represented by c in the cases of horses of ordinary size, moving at the rate of $2\frac{1}{2}$ miles per hour, it must be represented at any other velocity V by

$$c \times \frac{V}{2\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots (19)$$

The amount of friction of the joints of the horse we have no correct means of ascertaining; but the resistance to motion from such a cause can be but very little. Reasoning, as we have done before now, for the determination of the resistance due to the friction of the axles of machines in general, and supposing the friction of the rubbing surfaces of these joints not to be more than that of like surfaces of best mechanical workmanship, this resistance may be expressed by

$$\frac{w}{20} \times \frac{1}{40} = \frac{1000}{800} = 1\tfrac{1}{4} \text{ lbs.} \ldots\ldots (20)$$

in which expression the length of the horses leg is supposed to be 40 inches and the diameter of the joints 2 inches, and w or the weight of the horse 1000lbs.

The resistance to motion occasioned by the sinkage of the feet in the ground although of importance when the surface is penetrable to a considerable degree, yet will be found of little moment upon a road in an ordinary travellable state of repair. It is evident the extra muscular exertion which must be spent in all such cases above that necessary upon a hard surface is equal to the amount of *work expended* in pressing the horses feet through the surface upon which he walks.

Let us represent the greatest depth to which the foot sinks by D, any lesser depth by x, the weight of the horse by w, and suppose the resistance to vary as the n^{th} power of the depth penetrated. Then the *work expended* in compressing an element of depth is

$$dw = w \times \frac{x^n \, dx}{D^n}$$

$$\therefore w = \frac{w}{D^n} \times \int_D^0 x^n \, dx = W . \frac{D}{n+1}$$

This expenditure of power occurs at each step or length l passed over and is equivalent to the force of gravity upon a plane whose sine of angle of acclivity is $\frac{D}{l.\,(n+1)}$. The resistance from the sinkage of the feet will therefore be the same as the constant stress.

$$w \times \frac{D}{l.\,(n+1)} \ldots\ldots\ldots\ldots (21)$$

To exemplify this, suppose in ordinary cases $D = \frac{1}{4}$th of an inch, $l = 30$ inches, and $n = 2$. The expression will then be

$$1000 \times \frac{\frac{1}{4}}{30 \times (\,2+1)} = \frac{1000}{360} = 2\tfrac{3}{4}\text{lbs.}$$

If we now connect equations 19, 20, and 21 and substitute the value of p obtained therefrom in equation 18 we have

$$(22) \ldots\ldots M = TV \times (P + c\,\frac{V}{2\frac{1}{2}} + 4).$$

Now let us suppose that an ordinary good horse is capable of drawing on a level road, in his usual days work, one ton weight besides the car at a velocity of 2½ miles per hour for 6 hours, and that four other such horses under like circumstances draw a stage coach with passengers, &c. at a velocity of 10 miles per hour a distance of 8 miles or for ⅘th of an hour; the value of P will in the former case be 120lbs, and in the latter 40lbs. Inserting these respective values of T, V, and P in equation (22), and observing that under all circumstances M is constant, we therefore have

$$15 \times (124 + c) = 8 \times (44 + 4c)$$

$$17c = 1508$$

$$\therefore c = 88.8$$

$$\therefore 15 \times (124 + 88.80) = M = 3192$$

Substituting now the obtained values of c and M in equation (22)

$$TV \times (P + 35\tfrac{1}{2}\ V + 4) = 3192 \ldots\ldots (23)$$

In these calculations let it be remembered that T represents the duration of the day's work in *hours*, V the velocity in *miles* per *hour*, and P the stress in *pounds avoirdupois*.

There results from equation (23) the following independent expressions for level roads:

$$P = \frac{3192}{TV} - \{35\tfrac{1}{2}\ V + 4\} \quad \ldots. \quad (24)$$

$$T = \frac{3192}{V \times (P + 35\tfrac{1}{2}\ V + 4)} \quad \ldots. \quad (25)$$

$$V = \sqrt{\frac{90}{T} + \frac{(P+4)^2}{5041}} - \frac{P+4}{71} \ldots. (26)$$

To give an example, Let it be required to find the available draught of a horse upon a level road, if he draws at the rate of 5 miles per hour for 3 hours each day. Here $V = 5$, and $T = 3$. substituting therefore in equation (24)

$$P = \frac{3192}{3 \times 5} - (35\tfrac{1}{2} \times 5 + 4) = 31\tfrac{1}{3}\text{lb.}$$

Again let it be required to find the velocity with which a horse can accomplish his days work when he draws for 2 hours with an available force of 40lbs. In this case $P = 40$, and $T = 2$; then substituting in equation (26)

$$V = \sqrt{\frac{90}{2} + \frac{44^2}{5041}} - \frac{44}{71} = 6.08 \text{ miles per hour.}$$

It is evident all such deductions as those we have now obtained must be confined within certain limits. For instance the constitution of ordinary horses renders them unable to exert a greater available power of draught than about 300lbs, to endure a longer days work than about 8 hours exclusive of the time occupied in feeding and resting, or to attain a higher velocity than about 15 miles per hour.

From equations (15) and (16) the stress on a horse attributable to the motion of his load W up or down a hill which is inclined at an angle S to the level is

$$W \times \{\cos. S \times \text{tang.} (R + a) \pm \sin S\}$$

Assuming tang. $(R + a) = \frac{1}{25}$ in ordinary cases and cos. $S = 1$, this expression will become

$$W \times \left(\frac{1}{25} \pm \sin S.\right).$$

Going down a hill when sin S is greater than $\frac{1}{25}$ the expression becomes negative, which shews that the stress is in an opposite direction to motion for the purpose of keeping the load within an uniform velocity. Under any circumstances therefore the resistance of the load will be

$$\left.\begin{aligned} &\textit{on a level, } P = \frac{W}{25}\ldots\ldots\ldots\ldots\ldots\ldots \\ &\textit{ascending, } P = W \times \left(\frac{1}{25} + \sin S.\right)\ldots\ldots \\ &\textit{descending, } P = W \times \left(\frac{1}{25} \sim \sin. S\right) \end{aligned}\right\}(27)$$

In like manner and for the same reasons, the value of p or the stress which a horse suffers in moving *himself* will be

$$\left.\begin{aligned} &\textit{On a level } p = 35\tfrac{1}{3}\,V + 4\ldots\ldots\ldots\ldots \\ &\textit{Ascending } p = 35\tfrac{1}{3}\,V + 4 + w \sin. S.. \\ &\textit{Descending } p = 35\tfrac{1}{3}\,V + (4 \sim w \sin. S) \end{aligned}\right\}(28)$$

If we substitute in Equa. 23 the particular values of P and p obtained from the expressions (27) and (28) we will have the following three general expressions from which V, W, or T may be determined in the case of ascending and descending as well as level roads.

$$\text{On a level } TV \times \left\{ \frac{W}{25} + 35\tfrac{1}{2}\, V + 4 \right\} = 3192 \,..\, (29)$$

$$\text{Ascending } TV \times$$
$$\left\{ W \times \left(\tfrac{1}{25} + \sin. S\right) + 1000 \sin. S + 4 + 35\tfrac{1}{2}\, V \right\}$$
$$= 3192 \ldots\ldots\ldots\ldots\ldots (30)$$

$$\text{Descending } TV \times$$
$$\left\{ W \times \left(\tfrac{1}{25} \backsim \sin S\right) + \left(4 \backsim 1000 \sin S\right) + 35\tfrac{1}{2}\, V \right\}$$
$$= 3192 \ldots\ldots\ldots\ldots\ldots (31)$$

That part of our expressions (29), (30), and (31) which is contained between the braces (or $P + p$) is the intensity of the muscular action; and we should think its maximum value in general for a day's work cannot exceed that of a horse which draws a net load of 2 tons, or a gross load of 5500℔s at 1½ miles per hour on a level road. According to this supposition the maximum value of the intensity of action would be 277℔s in an ordinary day's work.

The following Table shews the velocities with which an ordinary horse can draw different loads for 8 hours a day on a level road.

Duration of Days work 8 hours. Friction $\frac{1}{25}$th of gross load			Duration of Days work 8 hours. Friction $\frac{1}{25}$th of gross load.		
Gross load in lbs.	Draught of load in lbs.	Velocity in miles per hour.	Gross load in lbs	Draught of load in lbs,	Velocity in miles per hour.
No load	0	3.29	3250	130	1.96
250	10	3.14	3500	140	1.89
500	20	3.04	3750	150	1.82
750	30	2.92	4000	160	1.76
1000	40	2.80	4250	170	1.70
1250	50	2.68	4500	180	1.65
1500	60	2.57	4750	190	1.60
1750	70	2.47	5000	200	1.55
2000	80	2.36	5250	210	1.50
2250	90	2.28	5500	220	1.45
2500	100	2.20	6000	240	1.36
2750	110	2.11	6500	260	1.29
3000	120	2.03	7000	280	1.22

With respect to the construction of this Table we do not deem it necessary to say anything further than that it is calculated from the expression (23).

A subject of great importance presents itself to our notice here; namely, the determination of the effects of inclinations on roads where horse power is employed as the means of transport.

We all know even without going into calculations that an up and down road, when the inclinations are at all considerable, cannot be so favourable for the draught of heavy loads as the level road, because the advantages to be derived from the descent do not compensate in full for the disadvantages from the ascent. Our object now is to determine with accuracy the amount of this deficiency, with the view of enabling us to form a just comparison between different lines of road connecting the same termini as well as to ascertain how much the engineer would be warranted to increase the length of road for the purpose of lessening the inclinations or obtaining a level.

If one ton be assumed as the net load of a horse, his gross load will be 2240lbs. + 760lbs, the weight of the car, = 3000lbs, and if 8 hours be taken as the duration of his day's work, then according to equation (30) his velocity ascending a plane of 1 in 40 will be 1.45 miles per hour, and with the same load upon a level it would be 2.03 miles per hour. Thus while he advances a distance of 1.45 miles up the inclination he would have been able to travel 2.03 miles on a level; consequently the carriage on 1.45 miles of the ascent is as expensive as on 2.03 miles of the level. And 1.45 : 2.03 :: 1 : 1.4 miles, the length of a horizontal plane which is equivalent to 1 mile of the ascending plane of 1 in 40.

Again, descending the same plane with the same load, the velocity will be (Equa. 31) 2.55 miles per hour. Then 2.55 : 2.03 :: 1 : 0.79 miles, the length upon a level equivalent to 1 mile of the descending plane.

Therefore ascending and descending

$$\begin{array}{l} 1.40 \\ 0.79 \\ \hline 2.19 \\ \hline \end{array}$$

1.095 Mean equivalent horizontal plane.

From this we see that 10 miles of a road having a plane or a continued succession of planes of 1 in 40 is equivalent to nearly 11 miles of a level road.

The following Table of equivalent horizontal planes has been computed for other inclinations in a similar manner. It is however necessary to state that all acclivities greater than 1 in 25 were reduced to that inclination by increasing the unity of length, because the muscular stress of the horse on that rise is $\frac{3000}{25} + 120 + 4 + 42 = 286$lbs, being about the utmost he could endure, and if the rise is steeper, he must go partly from one side of the road to the other so as to bring the stress within that limit. For the same reason, all declinations steeper than 1 in 9.8 were reduced to that plane.

For instance upon a rising plane of 1 in 10 the muscular stress upon a horse is equal very nearly to the draught on a level + the force of gravity from the incline, or $120 + 4 + 42 \frac{3000}{10}$ = 466lbs, which far exceeds the limit of his power. In such case therefore he must in advancing 1 mile directly up the inclination traverse from side to side an acclivity of 1 in 25 and actually travel a greater distance.

Table shewing the Lengths of *Horizontal Lines* equivalent to several Ascending and Descending Planes; the length of the Plane being unity.

An ordinary Horse supposed to work 8 hours a day, and to draw a gross load of 3000lbs or a net load of 1 ton.

PLANES.	EQUIVALENT HORIZONTAL LINES.		
	Ascending.	Descending.	Mean of the two
1 in 5	8.32	3.27	5.79
10	4.16	1.65	2.90
15	2.90	1.06	1.98
20	2.08	0.83	1.45
25	1.66	0.70	1.18
30	1.55	0.74	1.14
35	1.45	0.77	1.11
40	1.40	0.79	1.09
45	1.35	0.81	1,08
50	1.31	0.83	1.07
55	1.285	0.84	1.062
60	1.261	0.853	1.057
65	1.238	0.860	1.049
70	1.215	0.871	1.043
80	1.194	0.879	1.036
90	1.173	0.890	1.031
100	1.154	0.898	1.026
150	1.103	0.919	1.011
200	1.074	0.931	1.0025
Level.	1.000	1.000	1.0000

The length of an Horizontal Road which would be equivalent to a Hilly one, such as *A B C D* and the section (Fig. 36) may at once be ascertained, by multiplying the length of each plane respectively by its Tabular numbers, as given in the fourth column of our Table of equivalent Horizontal Lines, and adding the products together. The sum will be the required length of a level road which could be travelled over in the same time and with the same expenditure of power.

Thus supposing the intercourse to be as much in one direction as in the other.

From *A* to *B*, 1 mile × 2.9 the Tabular No. for a Plane of 1 in 10 is	2.90 Miles.
From *B* to *C*, 1½ miles × 1.98, the Tabular No. for a Plain of 1 in 15, is	2.97 Miles.
From *C* to *D*, 4 miles × 1.45, the Tabular No. for a Plane of 1 in 20, is	5.80 Miles.
Equivalent Horizontal Road..	11.67 Miles.

IRISH AND SCOTCH ROAD ACTS.

CHAPTER X.

THE Act 6th & 7th Wm. IV. chap. 116, commonly called "*The Grand Jury Act,*" regulates the system under which County Roads are made and maintained in Ireland. The following extract contains some of the principal sections of that Act.

IRISH ROAD ACT.

156—And be it enacted, that the drivers of every kind and species of vehicle, and all persons riding or driving any animal or animals, laden or unladen, on any road, or in any street of any city or town in Ireland, shall keep their left hand side of the road or street in going and coming thereon, leaving the other side free to all other passengers; and when they may have occasion to pass any other persons going in the same direction with themselves shall in all cases where it is practicable take and go on the right-hand of such persons; and on every cart, car, or other carriage without springs, on any road upon which his Majesty's mails are conveyed in coaches, or any other road being a county road, the name and surname and residence of the owner of such vehicle shall be painted in white Roman letters one inch long at the least; and every car or cart drawn by one horse shall have a double rein extending back to such car or cart; and if any person shall wilfully refuse or neglect to drive or pass in manner aforesaid, or if any person shall drive any vehicle on any such road whereon the name of the owner is not painted, or without a double rein as aforesaid, it shall and may be lawful for any magistrate, constable, or turnpike keeper, to stop and detain such offender, and the vehicle and animal or animals on which or with which such offender shall be, and forthwith to carry or convey such offender before any justice of the peace for the county where such offence shall be committed, or for any person whatsoever to lodge information against such offender before any such justice; and upon being convicted thereof upon the oath of one credible witness, every such person so offending shall forfeit and pay any sum not exceeding five shillings, to be levied by distress and sale of the goods and chattels of such offender, or by distress and sale of the carriage and horse or horses or other beasts, and the goods therein or thereon, wherewith such offender shall have been travelling at the time of such offence, such distress to be made under the hand and seal of such justice, rendering the overplus (if any) after deducting the said fine and expenses of such distress and sale to the owner or owners, on demand; one half of the amount of the penalties so levied to be paid to the informer, and the remaining half to the minister or curate of the parish in which such offence shall be committed, for the use of the poor of such parish; and if distress sufficient for such penalty or penalties shall not have been seized or found it shall and may be lawful for such justice, and he is hereby empowered and required, to commit such offender so convicted to the common gaol for any time not exceeding one calendar month, unless such offender shall sooner pay and satisfy the said penalty or penalties: and every person offending as aforesaid shall likewise be liable to pay and satisfy the damages which shall happen in consequence of any such neglect or default as aforesaid.

157.—And be it enacted, that no house or part of a house, shall be built within thirty feet of the centre of any road, or within fifteen feet of the side thereof (except in the streets of corporate or market towns; and that if any person shall offend herein, every such person shall upon conviction before any justice of the peace forfeit and pay the sum of ten pounds, and the further sum of twenty shillings for every week after such conviction until the same shall be pulled down or removed; and no lime kiln or windmill shall be built within one hundred feet of the centre of any public road; and it shall be lawful for any justice at a general sessions of the peace to direct any house, lime kiln, or windmill built or building contrary to this act to be pulled down and to issue their orders to any constable or constables for that purpose, which order every chief and other constable shall aid and assist in executing; and the centre of the road for the purposes of this act shall be deemed to be the centre of the part thereof made with gravel or small stones.

158—And be it enacted, that it shall be lawful for any person whatsoever to seize and impound, or cause to be seized or impounded, any swine or beast which shall be found wandering upon any public road, or about the streets or passages of any town, in case the owner thereof shall not be known; and it shall be lawful for any justice of the peace to fine the owner of such swine or beast any sum not exceeding two shillings, and in case such penalty, and the expenses of impounding and detaining the same, when it shall be so impounded, shall not be paid within four days after imposing such fine, or after impounding the same, to cause such swine or beast to be sold, and out of the money arising from the sale thereof to pay such penalty, and expenses of impounding, keeping, and selling the same, rendering the overplus (if any) to the owner, due notice having been previously given of such sale, in which shall be inserted the name of the parish and townland where such swine or beast was seized, which notice shall be posted up in some conspicuous place in the parish where such beast was seized, and at the place where impounded, forty-eight hours at the least before the time of sale.

159—And be it enacted, that if any person shall scour, deepen, widen, or fill up any ditch or drain on the side of any road without the consent or direction of the county surveyor; or if the owner or occupier of any lands contiguous to any public road shall omit to scour any ditch or drain leading from such road, so as to allow the water to pass away, within ten days after Notice shall be given to him or her so to do by such surveyor or by the contractor for the repairs of such road, or shall suffer the passage of the water to be obstructed by making or leaving any way or passage from any road into the lands adjoining his or her house, without a sufficient pipe, sewer, or gullet underneath it; or if any person shall ride or drive any horse, beast, or cattle of any description willingly and unnecessarily on any footpath or shall steep or dry any flax, or burn any bricks or lime, or any weeds or vegetables for ashes, upon any public road, or within thirty feet of the centre of any such public road; or shall make any kind of fire on any public road; or shall cut turf or make any turf stack upon any public road or within thirty feet of the centre thereof; or build any wall or make any ditch, or dig any pit or drain, on any public road, or within thirty feet of the centre thereof, unless by authority of a presentment; or shall lay any dirt, dung, turf, straw, rubbish, or scourings of any ditches or drains, or any stones, bricks, timber, sand, clay, or lime, on any public road, or within thirty feet of the centre thereof; or shall leave on any public road any plough or harrow, or any cart, car, dray, or other carriage, without the horse or horses or other beast or beasts being harnessed thereto, unless such carriage shall have been accidentally broken down there; or shall spread any linen, blanket, or cloth for winnowing corn within thirty feet of the centre of any public road; or shall leave any dead beast on any road, or within thirty feet of the centre thereof, unless in a house or yard enclosed with walls; or shall beat any flax, or thrash or winnow any corn, or erect any may-pole or may-bush or sign-post, on any road; or shall keep any cur-dog, mastiff, or bull-dog, without having a block of wood of the weight of five pounds at the least fastened to the neck of such dog, within fifty yards of any public road; or shall, without the consent of such surveyor or contractor, scrape any public road, or cut any sods or turf on the side of any such road, or take any earth, clay stone, or gravel therefrom; or shall lead or drive any car or carriage with timber, boards, or iron laid across, so as that either end shall project two feet beyond the wheels or sides thereof; or shall draw any timber or stones along any part of a public road, without being supported by wheels from touching the same; every person so offending shall, upon conviction by oath of one credible witness, before any justice of the peace within his jurisdiction, or upon the view of any justice, forfeit and pay a sum not exceeding twenty shillings for every such offence; and it shall be lawful for any such surveyor or contractor to fill up any ditch or drain which shall be scoured, deepened, or widened, or to scour any drains which have been filled on the side of any road, without such direction or consent, and to scour or deepen any drain or ditch leading from any road which shall be omitted to be scoured or deepened after such notice as aforesaid, and to remove any way or passage from any road into any adjoining land or to any house which may obstruct the free passage of the water, and to re-make the same by building a gutter, sewer, or arch therein; and it shall be lawful for any such surveyor, or for any other person by the order of any justice of the peace or any such surveyor, to remove any bricks, or weeds, or vegetables, for making ashes, or other materials, which shall be burning, or any flax which shall be steeped or drying, contrary to the provisions of this act, and to pull down any sign-post, may-pole, or may-bush, and to pull down or fill up and level any wall, drain, or ditch which shall be built or made, or begun to be built or made contrary to this act, and to remove the carcase of any dead beast which shall remain in or near any public road contrary to this act, and to levy the expense of so doing by distress and sale of the goods of the offender, or of the occupier of the lands adjoining the place where such nuisance shall be committed, rendering the overplus [if any] to the owner, after deducting the sum of one shilling in the pound for the expense and trouble of taking such distress.

162—And be it enacted, that every county surveyor and every contractor for any work to be executed by grand jury presentment, shall have power and authority to dig for, raise and carry away, in or out of any lands, not being a deer park, bleach-green, orchard, walled garden, haggard or yard, or planted walk, lawn, or avenue to a mansion house, any gravel, stones, sand, or other materials, whether the same be found in the same or any adjoining county, which may be wanted for the building, rebuilding, enlarging, or repairing any bridge, arch, gullet, pipe, or wall, or for the making, repairing, or preserving any road or foot-path; and such surveyor or contractor is hereby further empowered to make drains in order to carry off water which might injure any bridge, gullet, arch, pipe, wall, or road, in or through any lands, not being a deer park, bleach-green, orchard, walled garden, haggard or yard, or planted walk, lawn or avenue to a mansion house, and shall make such satisfaction for the damage done thereby, or by taking any such materials as aforesaid, as shall be assessed by three substantial householders which householders shall view the ground immediately previous to and immediately after such damages shall be committed, one of such householders to be named by the owner or occupier of the land, and another by the surveyor or contractor, and the third by any neighbouring justice of the peace; and in case any surveyor or contractor shall refuse, or after four days notice in writing from such landholder, neglect to name a householder on his part, then one shall be named for him by such justice; and such three householders shall be sworn by such justice of the peace (previous to the damage being committed) to be appraisers of such damages as may occur, and to make a true estimate thereof, in which estimate the value of any stones, gravel or other materials shall not be included, but only the waste committed by breaking the surface and making a passage through the land, unless where such stones, gravel, or materials shall be taken from any quarries and gravel pits *bona fide* demised with liberty to work the same: provided nevertheless, that it shall not be lawful for any such contractor or surveyor to enter any lands for any such purpose against the will of the occupiers thereof, without the previous order of a justice of the peace, which order any such justice is hereby authorized and required to grant on its being proved to his satisfaction, that the gravel, stones, or other materials sought cannot be conveniently procured elsewhere, nor such drain otherwise sufficiently made or cleansed.

163—And be it enacted, that it shall not be lawful for any such surveyor or contractor to dig, raise, and carry away any gravel, stones, sand, or other materials from the side of any public road, or from any beach or sea shore, whereby a public road, or bulwark, or defence to any building, or any land adjoining any road, may be injured; and that any person who shall be convicted thereof, on the oath of one or more credible witnesses, before any justice of the peace, shall for every such offence forfeit aud pay a sum not exceeding five shillings for every cart load of such gravel, stones, sand, or other materials, so dug, raised, or carried away, to be levied, by warrant of distress under the hand and seal of such justice, off the goods and chattels of such offender.

164—And be it enacted, that if any person shall wilfully prevent, assault, or threaten to assault any surveyor or contractor in the execution of his duty, or any person or persons employed by proper authority in surveying or measuring, or laying out any line intended for a new road, or if any person shall wilfully destroy, pull up, deface, or injure any surveyor's instruments or implements used in public works, or any milestone, milepost, or direction post, or any bridge, battlement, wall, railing, mound, or fence, erected or repaired by presentment, or shall wilfully break, deface, pull down, or take away any stones out of any such battlement, wall, mound, or fence, or out of any court-house, gaol, house of correction, pier or other buildings, or out of any bridge, pipe, arch, or gullet, built or repaired by presentment, every person so offending shall forfeit and pay for every such offence, upon conviction by the oath of one credible witness before any two justices of the peace at petty sessions, such sum not exceeding ten pounds as the said justices shall think fit; and in case the same shall not be paid, such justices are hereby empowered and required to commit such offender to any gaol, bridewell, or house of correction, for any time not exceeding three months, or until the said forfeiture shall be paid; and it shall be lawful for the treasurer of the county in which any such injury may have been done, if directed by the Grand Jury so to do, to commence and prosecute an action on the case against any person or persons by whom such injury may have been committed, and for recovering of damages to the amount thereof from such person or persons for the use of the county, and when the damages sought to be recovered do not exceed thirty pound, to sue for the same by civil bill before the assistant barrister, and in every such proceeding the property so injured or destroyed shall for the purposes of such proceeding be deemed to be the property of such treasurer.

165—And be it enacted, that in case at any time hereafter any public work erected or repaired by presentment of a grand jury, shall be wantonly or maliciously damaged or destroyed, it shall be lawful for the county surveyor and he is hereby required to apply at the presenting sessions of the district in which such work is or was situate, holden next after the discovery by him of such damage or destruction, for the repair or reconstruction of such work, and such proceedings shall be had on such application as on any other application by such surveyor, save only that in case any presentment shall be made by the grand jury in consequence thereof, the amount of such presentment shall be levied either off the parish in which such work is or was situate, or such portion thereof as the grand jury shall think proper.

SCOTCH ROAD ACT.

The Highways of the County of Forfar in Scotland are managed under the Act 50th Geo. III. chap. 120, which has worked very advantageously. The following are among the principal Sections of that Act.

17—And be it enacted, that the trustees, or any three or more of them in the said districts, at their first meeting, or any adjourned meeting, shall be empowered to name a preses or chairman of their meeting, and a clerk during pleasure; and that they shall superintend and have the direction and cognizance of the several roads and bridges within their respective districts; and shall have power to appoint the order in which the same shall be made and repaired, and to appropriate the monies and services to be exacted and raised by virtue of this act from each district, but in such a manner that the money or services exacted from each parish shall be laid out upon the roads of that parish only, unless two thirds of the trustees having property in any parish shall agree that the whole or any part of such money or services should be applied to other roads; and provided that the money or services assessed upon or exacted in country parishes shall be wholly expended or applied on roads not turnpike, excepting the money levied in burgh and upon burgh roods, which may be laid out as herein-after provided, and also excepting the share of each parish in the expence of clerks, collectors, and surveyors, overseers, and other officers, which proportion shall be regulated by the district meetings.

24—And be it further enacted, that if any district shall neglect or omit to lay before said general meeting an account of the application of the assessment and composition money of the preceding year within that district, in that case the said general meeting are hereby empowered and required to appoint a committee of their own number, to inquire into the cause of the said neglect, and to report to them at their next general meeting, or adjourned general meeting; and if it shall appear that the trustees of the said district have neglected to meet, or to levy the assessment for the preceding year, or shall have neglected to lay out said money upon the repairs of the roads and bridges after having levied it, in that case the said general meeting are hereby empowered and required to appoint a collector or collectors, and to levy the said assessment and composition money, and likewise to name a committee of three or more of their own number, who shall be vested with all the powers given by this act to the district meetings, for the application of said assessment or composition money towards the repairs of the roads and bridges within the respective parishes where it is levied.

33—And be it further enacted, that the said trustees, in their general or district meeting, or a quorum of them, which is hereby declared to be seven at a general meeting, and three at a district meeting, shall, and they are hereby authorized to cause the highways or roads, bridges, and ferries, within the said county, to be amended, widened, and repaired in such manner as they shall think proper; and to settle the direction of any of the said roads; and to make or cause to be made, causeways; and to cut or make drains, ditches, or trenches through any grounds lying contiguous to the said roads; and to make passage for the water, where it shall be found necessary, from such ditches or trenches through the ground of any adjacent proprietor; and also to keep clear such drains, ditches, passages, or outlets; and the workmen, authorised by them, may go upon the said lands for that purpose: provided always, that reasonable satisfaction be made to the owner or occupier of such land for the damage to be done thereby: and if the said owner or occupier shall not be satisfied with the allowance offered by the said trustees, he shall be at liberty to apply to the quarter sessions, who shall have power finally to settle the same.

52—And be it further enacted, that the said trustees, or any three or more of them, or such person or persons as they shall appoint, may dig, gather, take, and carry away gravel, furze, heath, stones, or such like materials, out of the several grounds of any person where materials may be found, not being dug or raised for the private use of the proprietor of such grounds, for making, repairing, and amending the said roads, or for building arches and bridges as aforesaid, and to open accesses for carrying off the said materials, such accesses, and the places from which the said materials shall be proposed to be taken, being first marked out by any three or more of the said trustees, if so required by the said proprietor of such grounds, or his or her factor, or by the occupier thereof, they the said trustees making reasonable satisfaction out of the money arising by virtue of this act, to the owners or occupiers of the grounds respectively from which such materials shall be taken, or over which the same may be carried, for the damages to be done thereby; but if such proprietor, factor, or occupier shall not be satisfied with the compensation offered by the said trustees, the same shall be ascertained by a jury to be impannelled by the sheriff depute, or his substitute, in the same manner as herein-before directed for determining the